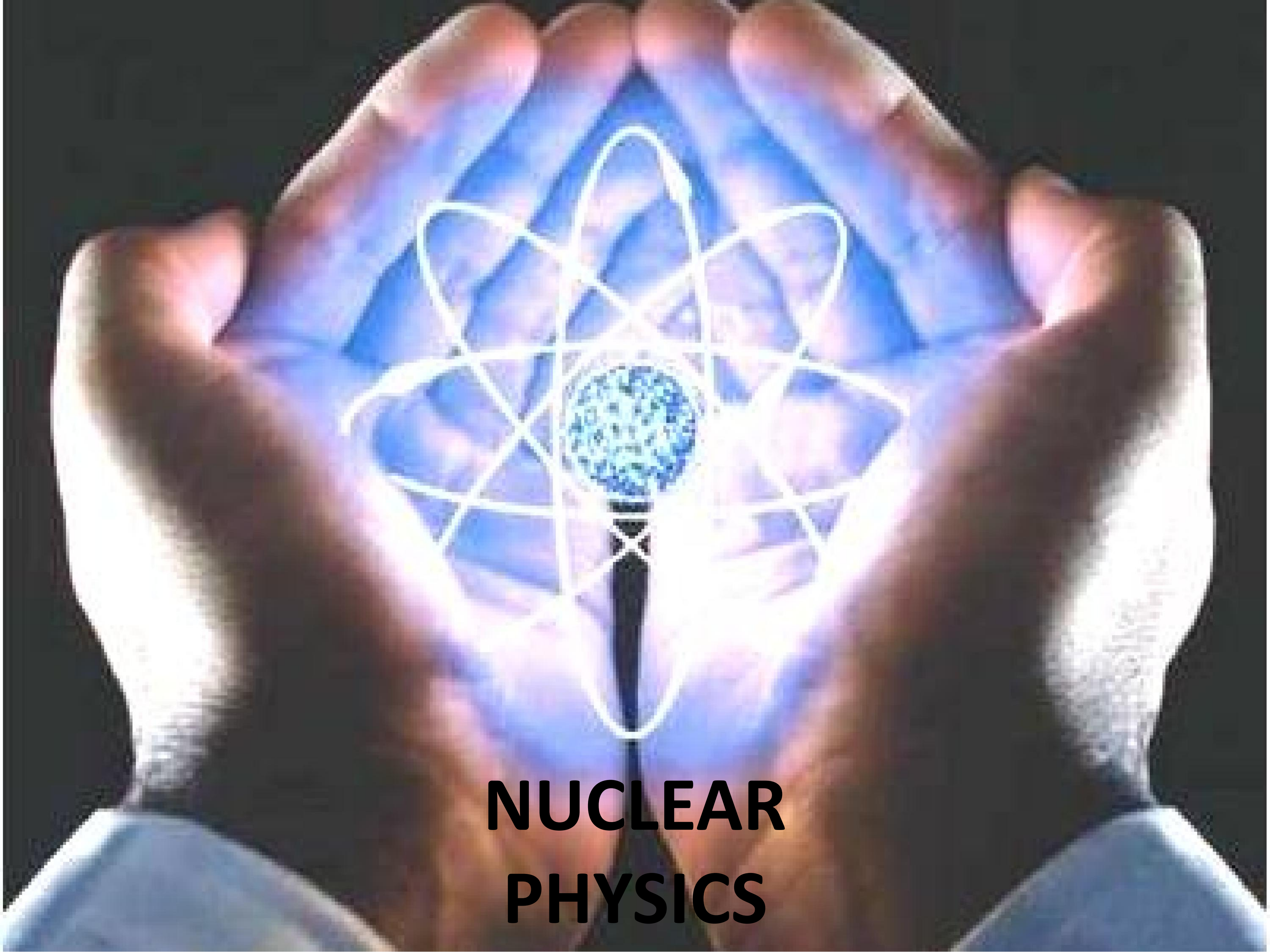
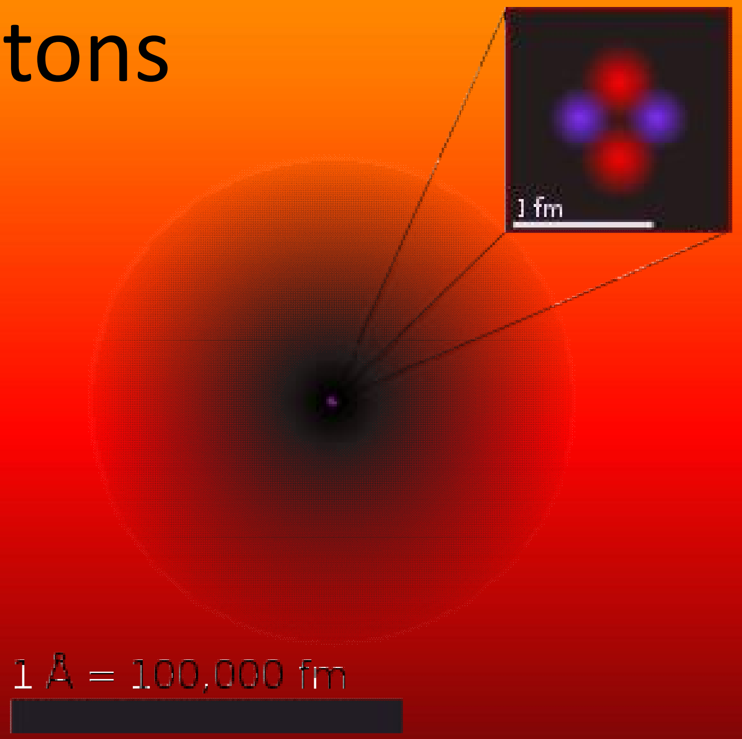
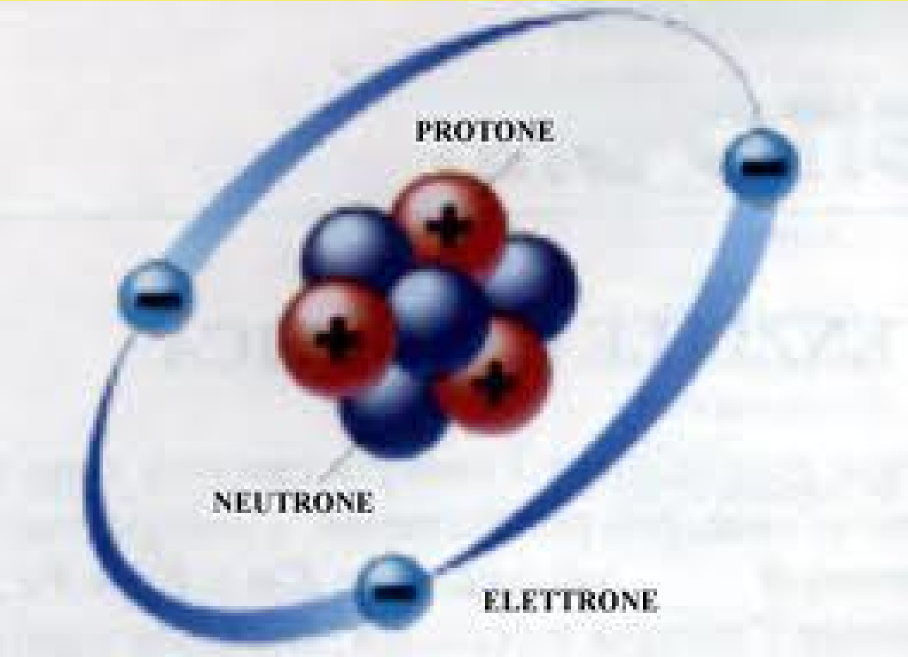


NUCLEAR PHYSICS

NUCLEAR PHYSICS

Nuclear physics is the field of physics that studies the atomic nucleus into its constituents: protons and neutrons, and their interactions.





←an atomic nucleus and electrons orbiting

Nuclear physics is different from the atomic physics that studies the atom, consisting of nucleus and electrons.

It is also different from sub-nuclear physics that studies the smallest particles of the nucleus.

The most commonly known applications of nuclear physics are nuclear energy, nuclear weapons, radiocarbon dating in geology and nuclear medicine. Nuclear physics is divided into nuclear structure physics that studies the properties of nucleus (such as mass and decay) and physics of nuclear reactions that studies the processes in which two or more nuclei interact in various ways to form other nuclei.

NUCLEUS

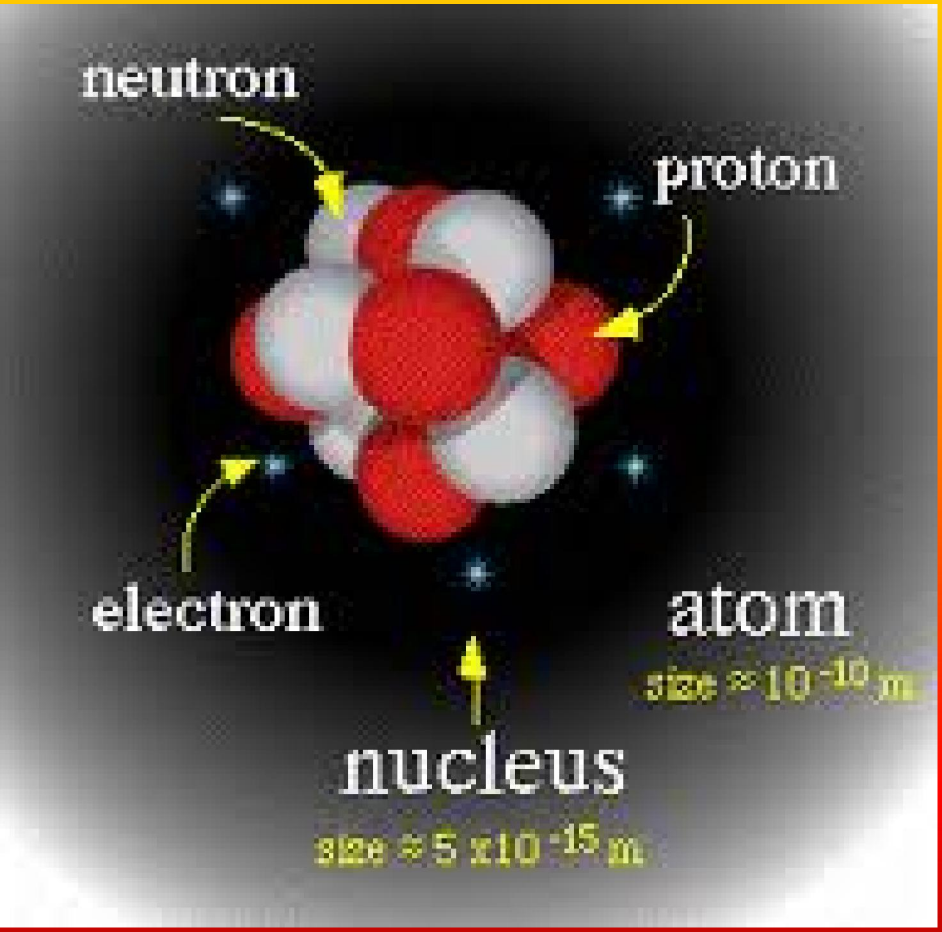
Unlike the atomic model, there is no single nuclear model capable of explaining all its properties, but there are several models that complement each other:

-the drop liquid model;

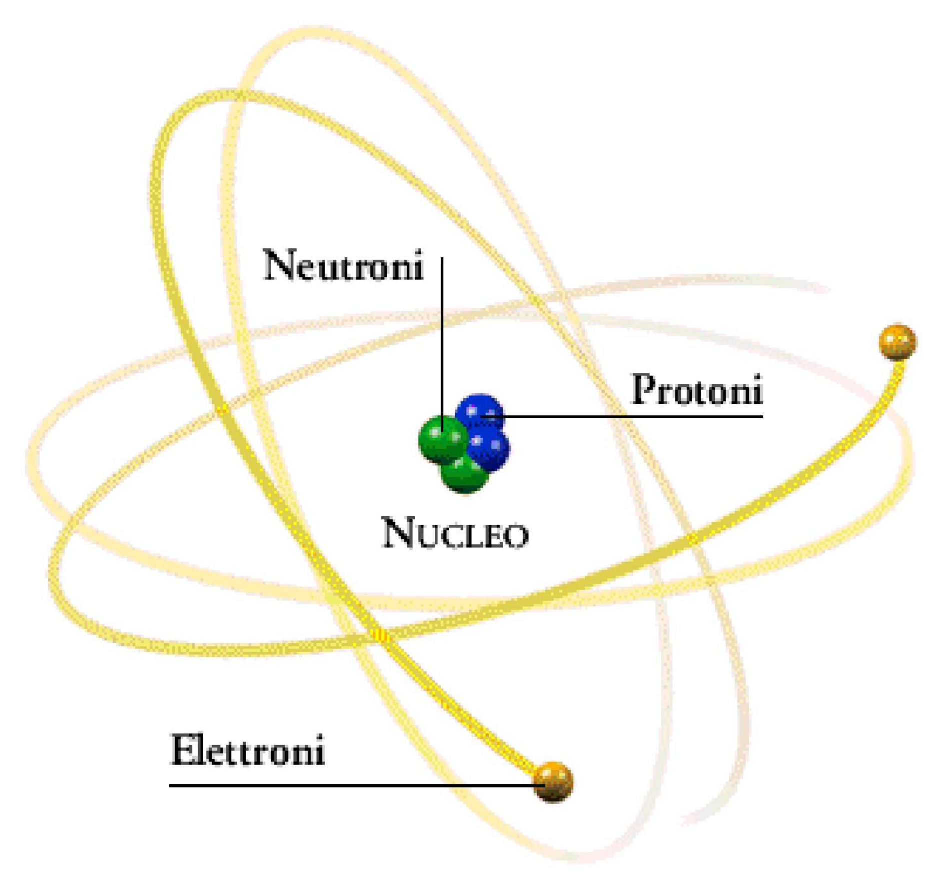
-the shell model;

-the collective model: an integration of other models

Even if the last model is the most complete, it leaves many problems without solution. The atomic nucleus is the central area, the most dense, of an atom, consisting of protons and neutrons.

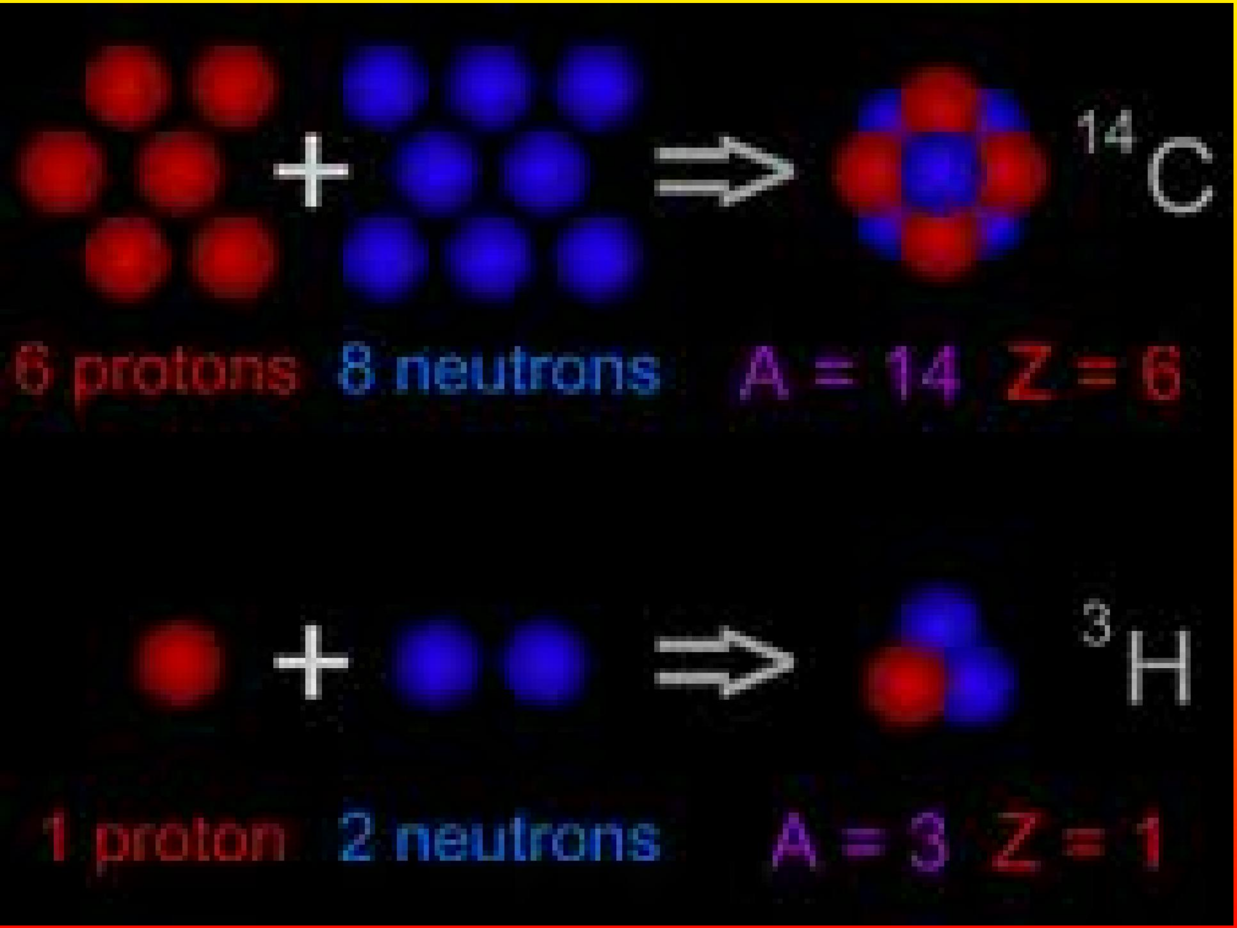


It has a radius of order of 10^-15 m (10^-15 meters=1 Fermi). Protons and neutrons are also called nucleons.

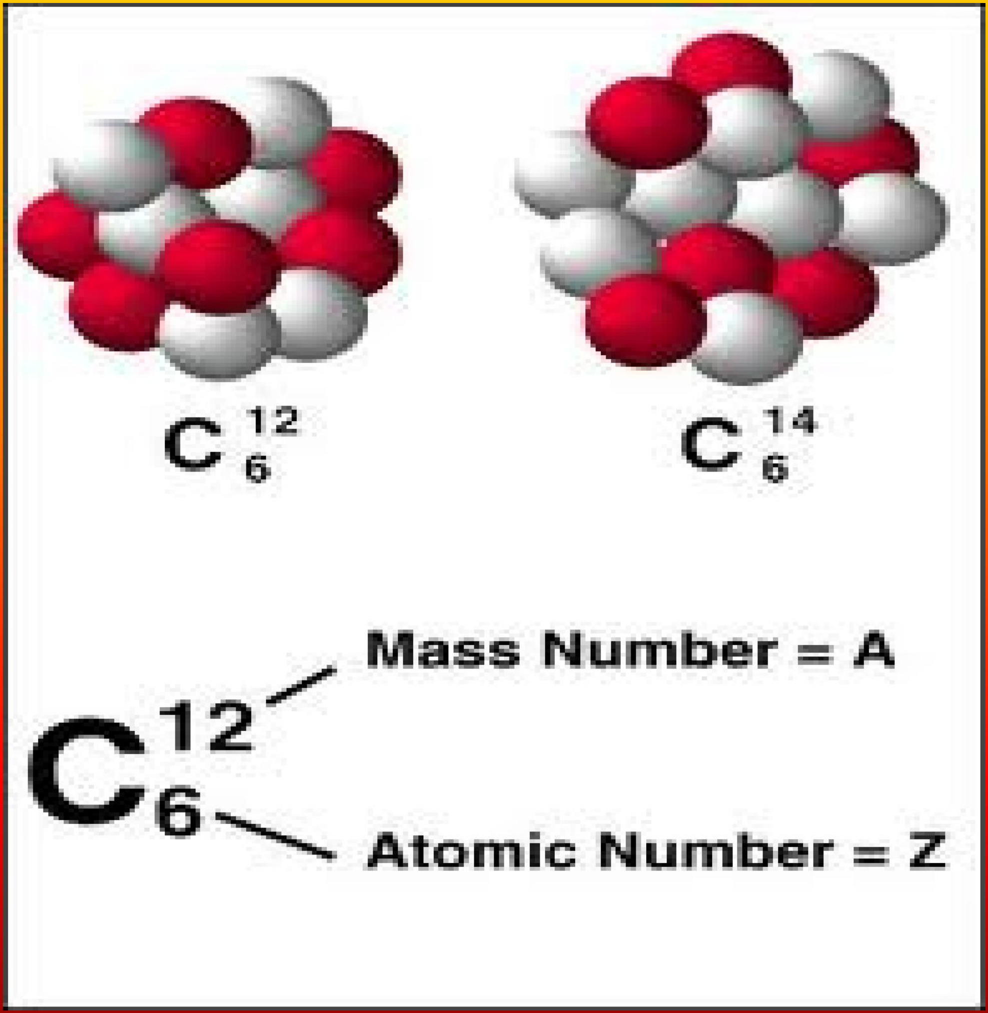


Protons have positive charge equal to 1,6*10^-19 C,

neutrons haven’t charge.



The nucleus is characterized by several parameters of which the most important are the mass number A, that represent the total number of nucleons, the atomic number Z, that is the number of protons and the number of neutrons N.

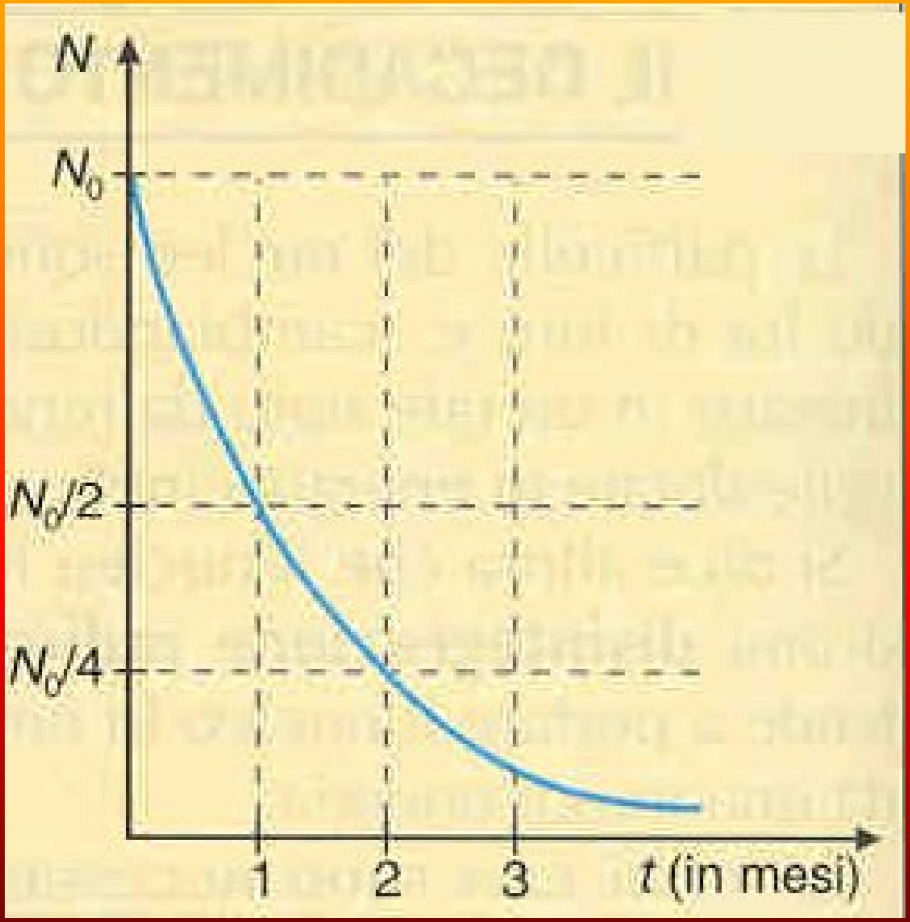


A=Z+N

Other important parameters are the total spin, parity, isotopic spin, and in the case of radioactive nuclei, the half-life.

The half-life (also indicated $\mathbf{t}_{1/2}$) is the period of time necessary for the amount of a substance to become half. Half-life is used to describe quantities undergoing exponential decay—for example, radioactive decay—where the half-life is constant over the whole life of the decay, and is a characteristic unit for the exponential decay equation.

$$N(t) = N_0\left(\frac{1}{2}\right)^{t/t_{1/2}}$$



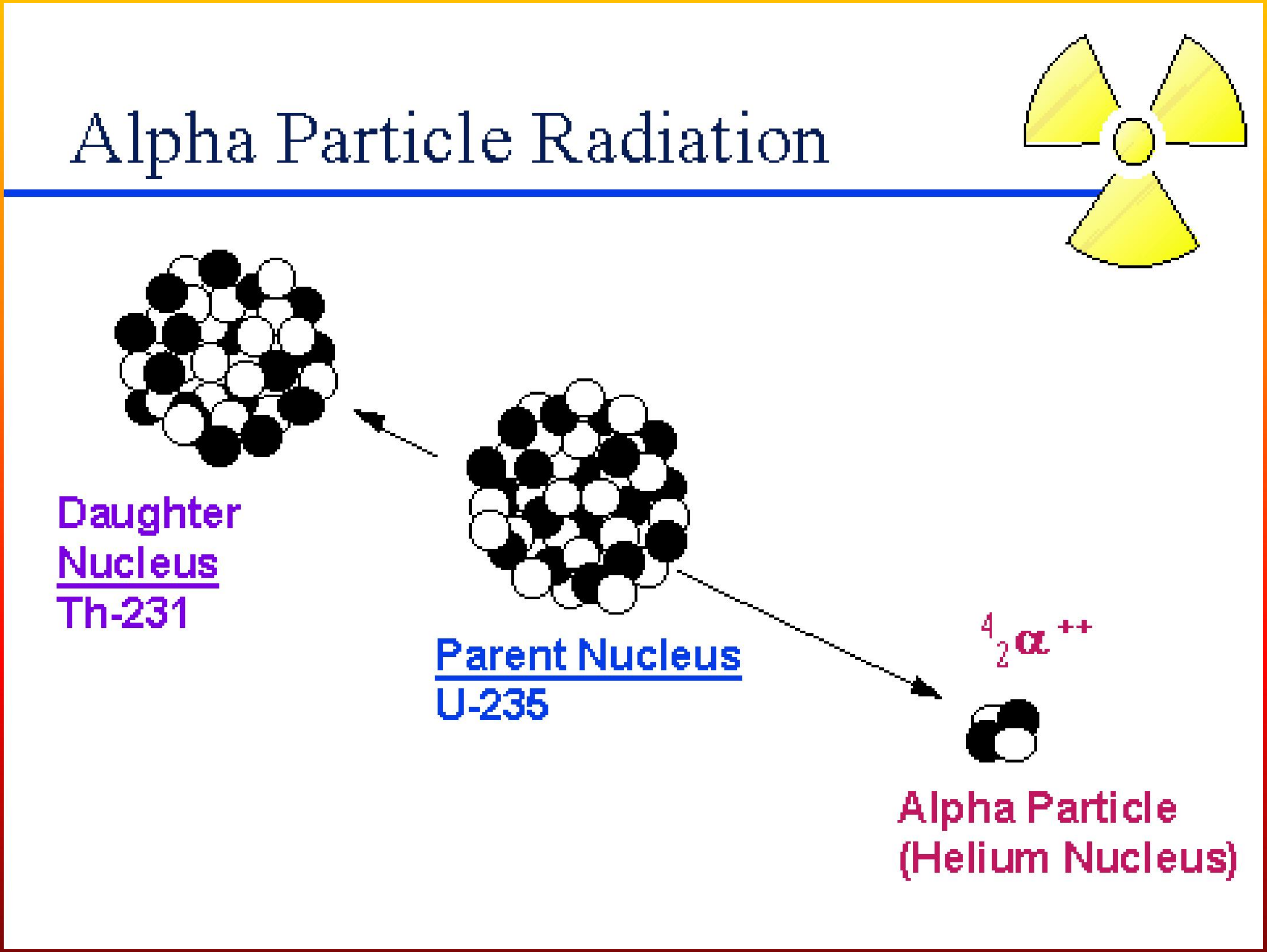
where N_0 is the initial quantity of the substance that will decay (measured in grams, moles...), N is the quantity that still remains after a time t, and $t_{1/2}$ is the half-life of the decaying quantity.

RADIOACTIVE DECAY

Radioactive decay is the process in which an atomic nucleus of an unstable atom loses energy by emitting ionizing particles (ionizing radiation). There are many different types of radioactive decay which are grouped into three large families: alpha decay, beta decay and gamma decay. A decay results when an atom with one type of nucleus, called the parent radionuclide, transforms to an atom with a nucleus in a different state, or to a different nucleus containing different numbers of nucleons. Either of these products is named the daughter nuclide. In some decays the parent and daughter are different chemical elements, and thus the decay process results in nuclear transmutation (creation of an atom of a new element).

Alpha decay is a type of radioactive decay in which an atomic nucleus emits an alpha particle (two protons and two neutrons) and decays into an atom with a mass number 4 less and atomic number 2 less.

$$^{238}_{92}U \rightarrow \, ^{234}_{90}Th + \, ^{4}_{2}He$$

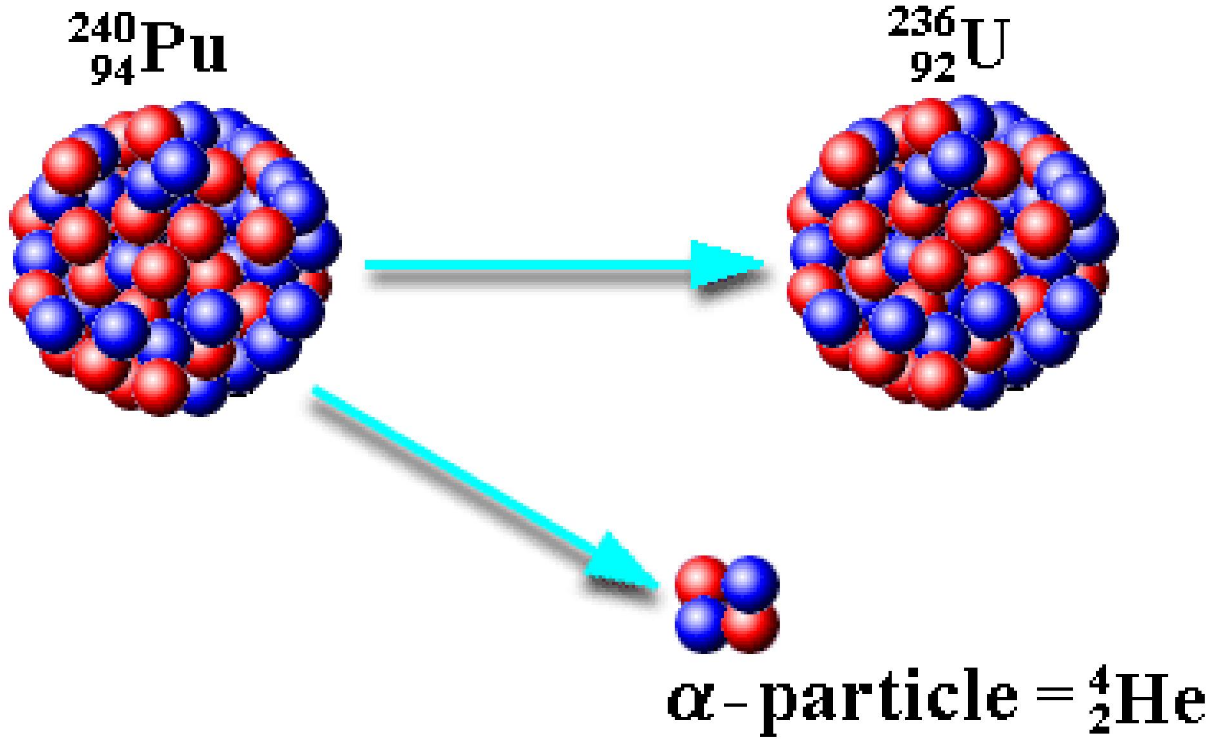


which can also be written as

$$^{238}U \rightarrow \ ^{234}Th + \alpha$$

where an alpha particle is the same as a helium-4 nucleus, which has mass number 4 and atomic number 2. Alpha decay is the most common form of decay where the parent atom ejects a defined daughter collection of nucleons, leaving another defined product.

alpha decay



Beta decay is a type of radioactive decay in which a beta particle (an electron or a positron) is emitted from an atom. There are two types of beta decay: beta minus and beta plus. The positron is the antiparticle of the electron. In the case of beta decay that produces an electron emission, it is called beta minus ($\beta-$), while in the case of a positron emission as beta plus ($\beta+$). In electron emission, an electron antineutrino is also emitted, while positron emission is accompanied by an electron neutrino.

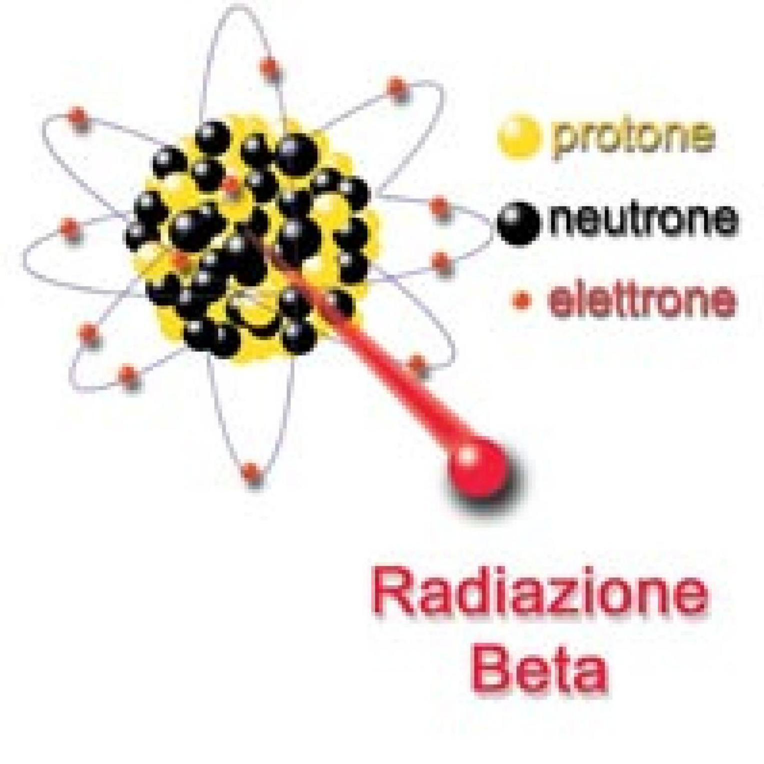
Beta decay is mediated by the weak force. β decay can occur in two ways:

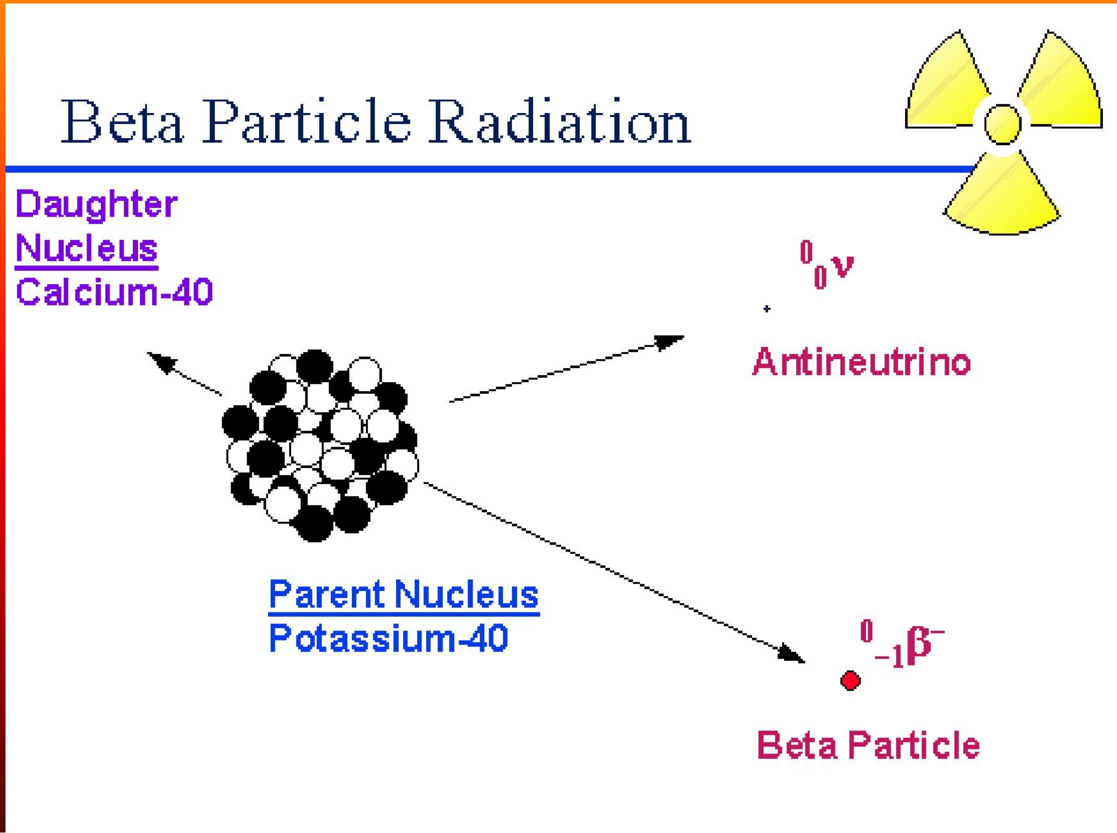
In β- decay, a neutron decays into a proton-electron pair plus one electron anti-neutrino. The proton remains in the atomic nucleus, while the other two particles are ejected. An example of beta decay is the decay of the radionuclide cobalt-60 (unstable) in the nuclide nickel-60 (stable):

$$^{60}_{27}Co \rightarrow \, ^{60}_{28}Ni + e^{-} + \bar{\nu}_e$$

In β+ decay, a proton decays in a neutron-positron pair plus one electron neutrino. An example of beta decay is the decay of the radionuclide fluorine-18 (unstable) in the stable nuclide oxygen 18:

$$^{18}_{9}F \rightarrow {}^{18}_{8}O + e^{+} + \nu_{e}$$


protone
neutrone
elettrone
Radiazione
Beta


Beta Particle Radiation
Daughter
Nucleus
Calcium-40
$^{0}_{0}\nu$
Antineutrino
Parent Nucleus
Potassium-40
$^{0}_{-1}\beta^{-}$
Beta Particle

In nuclear physics, gamma rays are a form of electromagnetic radiation produced by the so-called gamma decay. An example of generation of gamma rays:

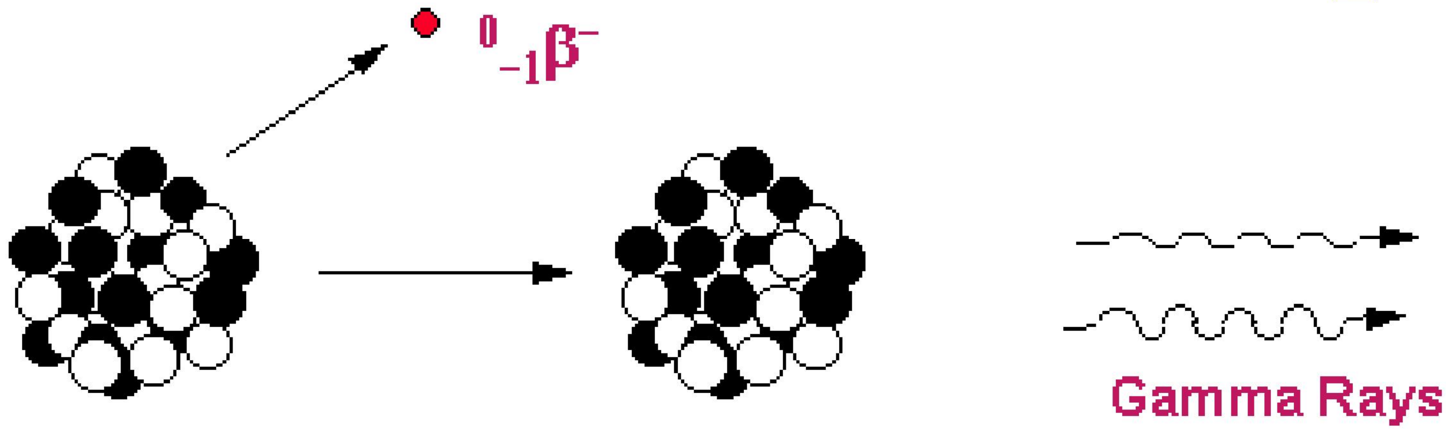
Before a group of cobalt-60 decays into an excited nickel-60 through beta decay:

$$^{60}_{27}Co \rightarrow \, ^{60}_{28}Ni^{*} + e^{-} + \bar{v}_{e}$$

then the nickel-60 passes its minimum energy state by emitting a gamma ray:

$$^{60}_{27}Co \rightarrow \, ^{60}_{28}Ni^{*} + \gamma$$

Gamma-Ray Radiation



<u>Parent Nucleus</u>
Cobalt-60

<u>Daughter Nucleus</u>
Ni-60

NUCLEAR FISSION

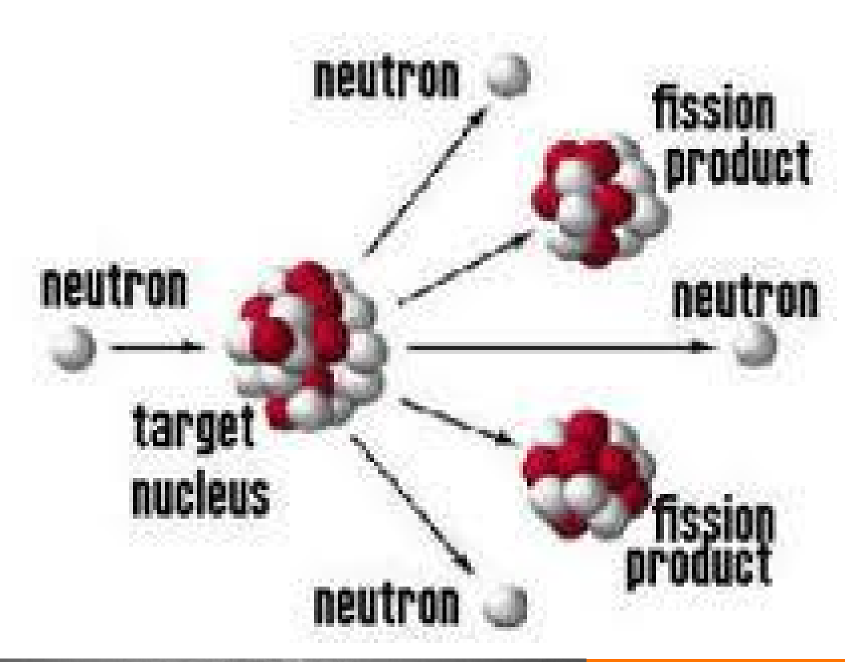
Nuclear fission is a nuclear reaction in which the nucleus of an element - for example, uranium-235 or plutonium 239 - decays into smaller fragments, or in the nuclei of atoms with minor atomic numbers providing a large amount of energy and radioactivity. Fission can occur spontaneously in nature (spontaneous fission) or be induced by neutron bombardment.

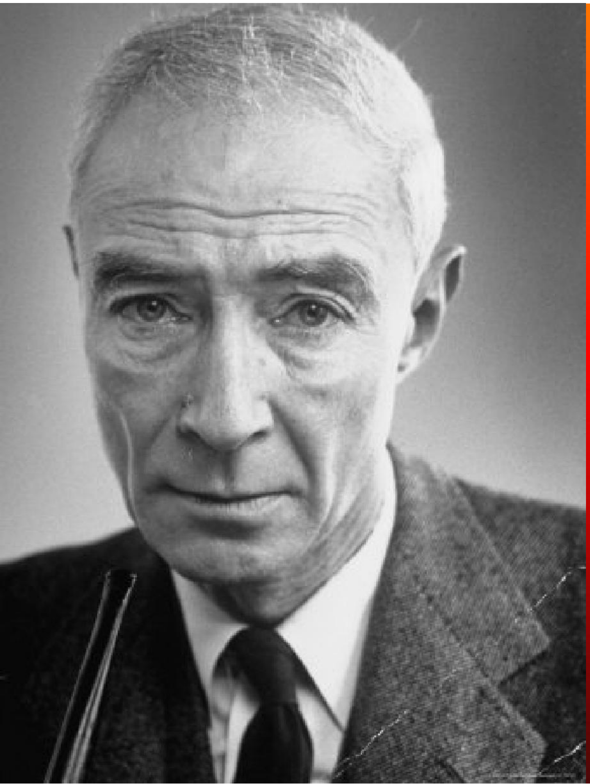
It is the nuclear reaction commonly used in nuclear reactors and in the simplest types of atomic bombs, such as uranium bombs (like the one that hit Hiroshima) or plutonium bombs (like the one that hit Nagasaki).

In nuclear fission, when a core of fissile material (which produces fission neutrons with any kinetic energy) or fissionable (only with high kinetic energy of neutrons, called fast) absorbs a neutron, it produces two or more smaller nuclei and a variable number of new neutrons.

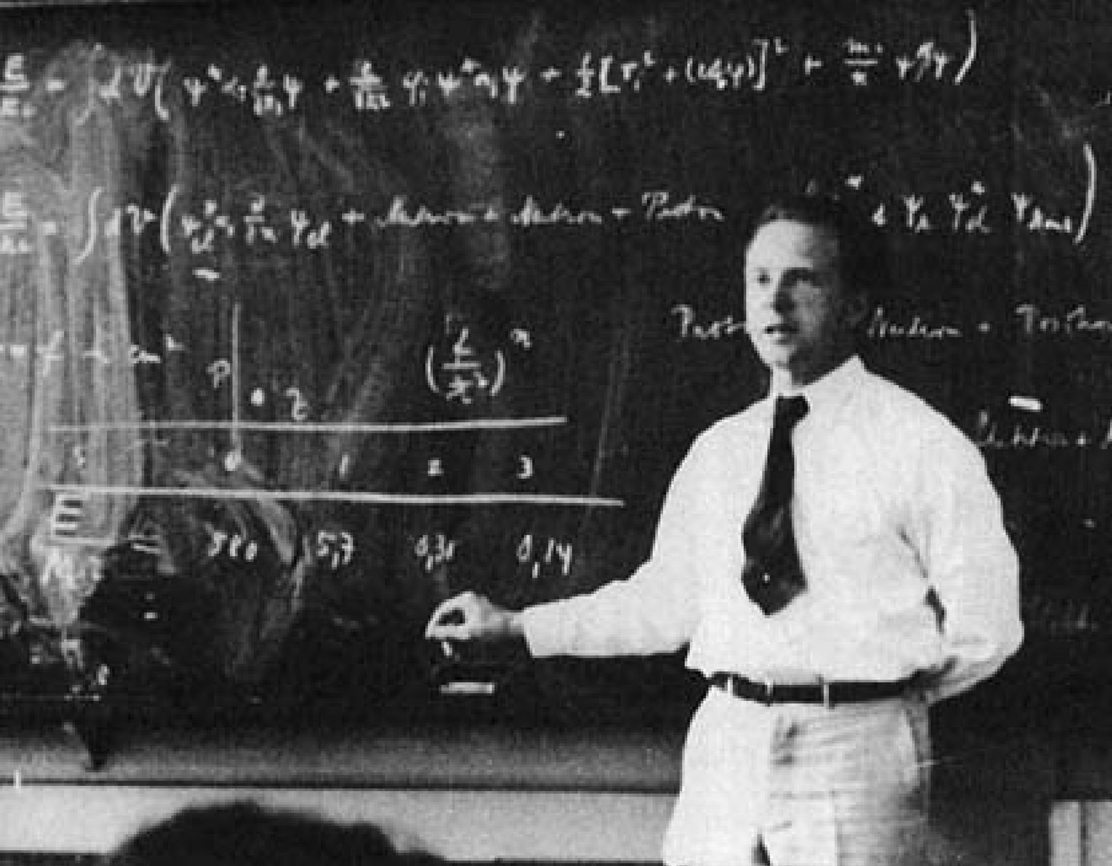
The isotopes are radioactive products from this reaction as possessing an excess of neutrons and undergo beta decay chain until you get to a stable configuration. Furthermore, in the fission products are normally 2 or 3 free fast neutrons. The total energy released by fission of a 235U nucleus is 211 MeV, a high quantity given by: $E=M_{(U\text{^}235+n)}\, c\text{^}2-M_p\, c\text{^}2$ (the general equation is E = mc ^ 2 by Albert Einstein). Where the first mass is the mass of the nucleus of 235U and of the incident neutron, the second mass is the sum of the masses of the cores and of the neutrons produced and c is the speed of light in vacuum (299,792.458 km / s).

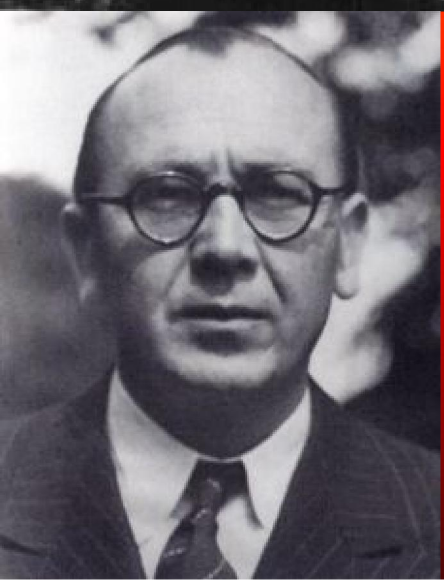
Nuclear fission was discovered in Germany in 1938 by Otto Hahn and Fritz Strassmann. The first atomic bomb was built during the USA's Manhattan Project led by Dr. Robert Oppenheimer. Nazi Germany also worked on two projects, one led by prof. Kurt Diebner and the other by Werner Heisenberg. Only the prof. Diebner probably made a prototype, but there are no reliable sources.





←Dr. Robert Oppenheimer



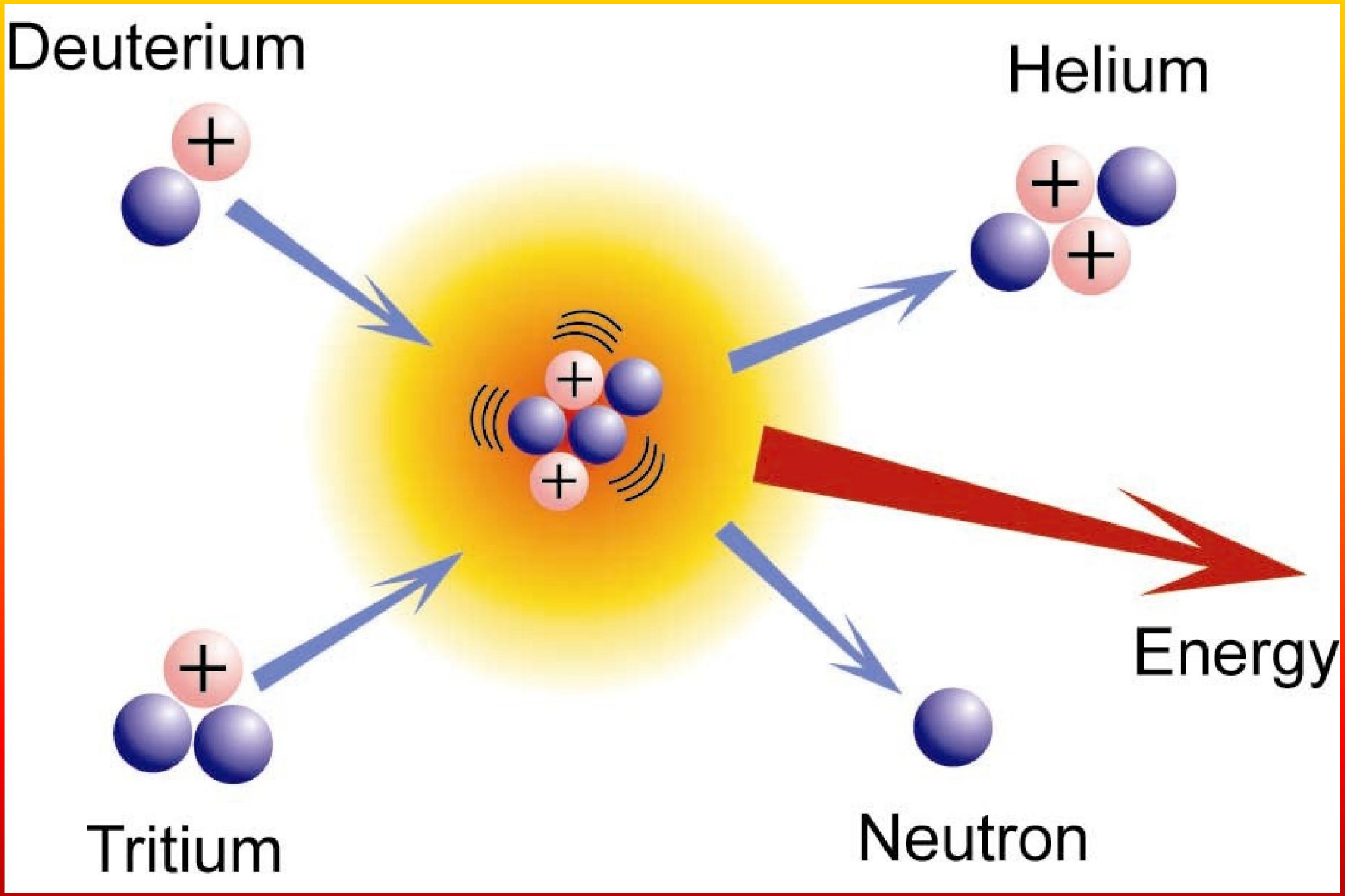


Werner Heisenberg

←prof Kurt Diebner

NUCLEAR FUSION

Nuclear fusion is the process of nuclear reaction in which the nuclei of two or more atoms are compressed so as to give precedence to the strong interaction on the electromagnetic repulsion, joining together and thus going to generate a core of greater mass of the nuclei reagents and, sometimes, one or more free neutrons, the fusion of elements up to atomic numbers 26 and 28 (iron and nickel) is exo-energy, which emits more energy than it requires the compression process, then absorbs energy (for the formation of heavier atomic nuclei). The fusion process is the mechanism that powers the Sun and other stars; within them - by nucleosynthesis -they generate all the elements that constitute the universe from lithium to uranium and is reproduced by man with the realization of the bomb H.


Deuterium
Helium
Energy
Tritium
Neutron