The Nuclides:

Approximately 2000 nuclides are known to exist. Each is characterized by an atomic number Z (the number of protons), a neutron number N, and a mass number A (the total number of nucleons—protons and neutrons). Thus, A Z N. Nuclides with the same atomic number but different neutron numbers are isotopes of one another. Nuclei have a mean radius r given by,

$$r = r_0 A^{1/3} \qquad (42\text{-}3)$$

where r_0 = 1.2 fm, 1 fm = 1 x 10^{-15} m, (pronunciation = femtometer)

The nucleus consists of protons and neutrons, the strong nuclear force binds them together. This force is very attractive in short ranges, has the same value for proton-proton, neutron-proton, or proton-neutron pairs.

Mass and Binding Energy:

Atomic masses are often reported in terms of mass excess,

$$\Delta = M - A \qquad (42\text{-}6),$$

where M is the actual mass of an atom in atomic mass units and A is the mass number for that atom's nucleus. *M - A is known as the mass excess*. The binding energy of a nucleus is the difference,

$$E_{be} = \sum (mc^2) - Mc^2$$

where $\sum(mc^2)$ is the total mass-energy of the individual protons and neutrons.

Mass– Energy Exchanges:

The energy equivalent of one mass unit (u) is 931.494 013 MeV. This means that if we are able to convert one atomic mass unit fully into energy we shall get 931.5 MeV (Mega Electron-Volt) energy according to Einstein's law of mass and energy. ($E = mc^2$).

If we draw the binding energy curve, it shows that middle-mass nuclides are the most stable and that energy can be released both by fission of high-mass nuclei and by fusion of low-mass nuclei.

Radioactive Decay:

Most known nuclides are radioactive; they spontaneously decay at a rate R (- dN/dt) that is proportional to the number N of radioactive atoms present, the proportionality constant being the disintegration constant λ. This leads to the law of exponential decay:

$$N = N_0 \, e^{-\lambda t}$$

The half-life

$T_{1/2} = (\ln 2)/\lambda$ of a radioactive nuclide is the time required for the decay rate R (or the number N) in a sample to drop to half its initial value.

Atomic Radiation:

We can get three types of radiation from an unstable nucleus. They are alpha decay, beta decay, and gamma decay. Generally, isotopes of different elements are unstable due to their higher proton number. This instability results in the radioactive decay of the three kinds. After the decay, the nuclei become much stable. Among the three types of radiation, gamma is the most energetic and thus the most destructive.

Alpha Decay:

Some nuclides decay by emitting an alpha particle (a helium nucleus, (^{4}He). Such decay is inhibited by a potential energy barrier that cannot be penetrated according to classical physics but is subject to tunneling according to quantum physics. The barrier penetrability, and thus the half-life for alpha decay, is very sensitive to the energy of the emitted alpha particle.

Beta Decay:

In beta decay, either an electron or a positron is emitted by a nucleus, along with a neutrino. The emitted particles share the available disintegration energy. The electrons and positrons emitted in beta decay have a continuous spectrum of energies from near zero up to a limit K_{max} ($Q = -\Delta mc^2$).

Gamma Decay:

Gamma decay is high energy electromagnetic radiation that comes from the nucleus. Unstable nuclei that are not in a suitable position to decay an alpha particle or beta radiation emit gamma-ray and shed some of their excess energy.

Radioactive Dating:

Naturally occurring radioactive nuclides provide a means for estimating the dates of historic and prehistoric events. For example, the ages of organic materials can often be found by measuring their ${}_{14}\mathrm{C}$ content; rock samples can be dated using the radioactive isotope ${}_{40}\mathrm{K}$. When a living being dies, they stop taking food, so if they contain carbon or potassium in them, they start decaying. By calculating the number of radioactive carbon or potassium present and using the formula for half-life the age of the material can be found easily. This is the principle that is used in radioactive dating.

Radiation Dosage:

Three units are used to describe exposure to ionizing radiation. The becquerel (1 Bq = 1 decay per second) measures the activity of a radioactive source.

The amount of energy actually absorbed is measured in grays, with 1 Gy corresponding to 1 J/kg.

The estimated biological effect of the absorbed energy is measured in sieverts; a dose equivalent of 1 Sv causes the same biological effect regardless of the radiation type by which it was acquired.