

# Summary

The discovery of the neutron in 1932 solved several outstanding problems, including the understanding of the nuclear constituents and the origin of very penetrating radiation.

A nuclide  ${}^A_ZX$  has mass  $M$  and is composed of  $Z$  protons and  $N$  neutrons. Its mass number is  $A = Z + N$ . Masses are measured in terms of atomic mass units  $u$ . The radius of a nucleus is  $R = r_0 A^{1/3}$ , where  $r_0 \approx 1.2 \times 10^{-15} \text{ m} = 1.2 \text{ fm}$ . Electron scattering is useful to measure the size and shapes of nuclei. The properties of the nucleons are as follows:

Property	Neutron	Proton
Mass ( $u$ )	1.008665	1.007276
Charge ( $e$ )	0	+1
Spin ( $\hbar$ )	1/2	1/2
Magnetic moment ( $e\hbar/2m_p$ )	-1.91	+2.79

The study of the deuteron and nucleon-nucleon scattering indicates that the nuclear force is attractive and much stronger than the Coulomb force. However, it is effective only over a short range (up to about 3 fm). The nuclear force is charge independent and has a hard core.

A nuclide is stable if its mass is smaller than any other possible combination of the  $A$  nucleons. Stable nuclides tend to have  $N \approx Z$  for small  $A$  and  $N > Z$  for medium and large  $A$ . The total binding energy for a nuclide is

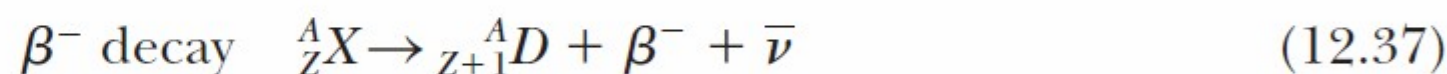
$$B({}^A_ZX) = [Nm_n + ZM({}^1_1\text{H}) - M({}^A_ZX)]c^2 \quad (12.10)$$

The von Weizsäcker semi-empirical mass formula is useful in predicting the nuclear binding energy. There are no stable nuclei with  $Z > 83$  or  $A > 209$ . Nuclei tend to be more stable with an even number of protons and/or neutrons. Nuclei near  ${}^{56}\text{Fe}$  have the highest binding energies per nucleon, and the average binding energy per nucleon for most nuclei is about 8 MeV.

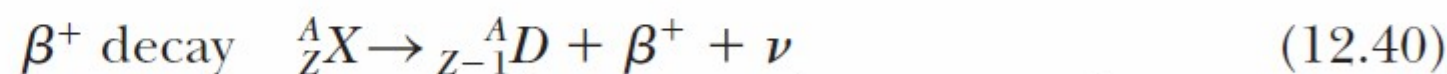
The radioactive decay law is  $N = N_0 e^{-\lambda t}$ , where  $\lambda$  is the decay constant and the half-life  $t_{1/2} = 0.693/\lambda$ . The activity  $R = \lambda N$ . A becquerel (Bq) is 1 decay/s. Radioactive decay occurs when the disintegration energy  $Q > 0$ . The four kinds of alpha and beta decay are



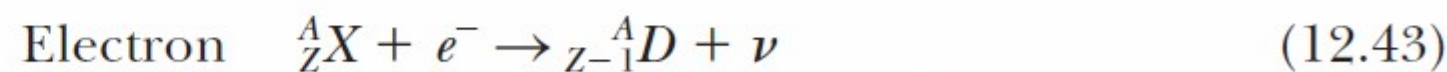
$$Q = [M({}^A_ZX) - M({}^{A-4}_{Z-2}D) - M({}^4_2\text{He})]c^2 \quad (12.31)$$



$$Q = [M({}^A_ZX) - M({}^A_{Z+1}D)]c^2 \quad (12.38)$$



$$Q = [M({}^A_ZX) - M({}^A_{Z-1}D) - 2m_e]c^2 \quad (12.41)$$



$$Q = [M({}^A_ZX) - M({}^A_{Z-1}D)]c^2 \quad (12.44)$$

There are only four radioactive series. For example, two of them begin with uranium isotopes,  ${}^{235}\text{U}$  and  ${}^{238}\text{U}$ . Radioisotopes are useful to date objects like the age of Earth and ancient objects. Radiocarbon  ${}^{14}\text{C}$  is one of the most useful.