Al-Mustansiriyah University
College of Science
Physics Department

Fourth Grade
Nuclear Structure
Dr. Waleed Jabbar Mhana
Dr. Hanaa Salih Sabaa

# Chapter One
# (Nuclear Concepts)

## (1-1) History

**The main stages of the nuclear physics are the following:**

- 1868 Mendeleev's periodic classification of the elements.
- 1895 Discovery of X-rays by Roentgen.
- 1896 Discovery of radioactivity by Becquerel.
- 1897 Identification of the electron by J.J. Thomson.
- 1898 Separation of the elements polonium and radium by Pierre and Marie Curie.
- 1908 Measurement of the charge +2 of α particle by Geiger and Rutherford.
- 1911 Discovery of the nucleus by Rutherford; "planetary" model of the atom.
- 1913 Theory of atomic spectra by Niels Bohr.
- 1914 Measurement of the mass of α particle by Robinson and Rutherford.
- 1924–1928 Quantum theory (de Broglie, Schrodinger, Heisenberg, Born, Dirac).
- 1928 Theory of barrier penetration by quantum tunneling, application to α radioactivity, by Gamow, Gurney and Condon.
- 1929–1932 First nuclear reactions with the electrostatic accelerator of Cockcroft and Walton and the cyclotron of Lawrence.

- 1930–1933 Neutrino proposed by Pauli and named by Fermi in his theory of beta decay.
- 1932 Identification of the neutron by Chadwick.
- 1934 Discovery of artificial radioactivity by Joliot-Curie.
- 1934 Discovery of neutron capture by Fermi.
- 1935 Liquid-drop model and compound nucleus model of N. Bohr.
- 1935 Semi-empirical mass formula of Bethe and Weizsacker.
- 1938 Discovery of fission by Hahn and Strassman.
- 1939 Theoretical interpretation of fission by Meitner, Bohr and Wheeler.

To these fundamental discoveries we should add the practical applications of nuclear physics. Apart from nuclear energy production beginning with Fermi's construction of the first fission reactor in 1942, the most important are astrophysical and cosmological. Among them are:

- 1938 Bethe and Weizsacker propose that stellar energy comes from thermonuclear fusion reactions.
- 1946 Gamow develops the theory of cosmological nucleosynthesis.
- 1953 Salpeter discovers the fundamental solar fusion reaction of two protons into deuteron.
- 1957 Theory of stellar nucleosynthesis by Burbidge, Fowler and Hoyle.
- 1960 Detection of solar neutrinos
- 1987 Detection of neutrinos and $\gamma$-rays from the supernova.

## (1-2) Introduction

Nuclei sit at the center of any atoms. Therefore, understanding them is of central importance to any discussions of microscopic physics. As you know, nuclei are composed of protons and neutrons. The number of protons is the atomic number (Z), and the mass number (A) is equal to the total number of nucleons (a collective name for protons and neutrons), Therefore, A = N + Z where (N) is the number of neutrons. Isotopes are denoted by ${}^{A}_{Z}\mathbf{X}_{N}$ or more often by ${}^{A}_{Z}\mathbf{X}$ or just ${}^{A}\mathbf{X}$ , where X is the chemical symbol and A is the mass number, for example ${}^{238}_{92}\mathbf{U}_{146}$.

**(1-3) Definitions and Units**

Nuclide = nucleus with a specific N and Z (e.g. ${}^{14}_{6}\mathbf{C}_{8}$)

Isotope = two nuclei with same Z and different N. (e.g. ${}^{12}_{6}\mathbf{C}_{6}$, ${}^{14}_{6}\mathbf{C}_{8}$)

Isotone = two nuclei with same N and different Z (e.g. ${}^{12}_{6}\mathbf{C}_{6}$, ${}^{14}_{8}\mathbf{O}_{6}$)

Isobar = two nuclei with same A, different Z and N (e.g. ${}^{14}_{7}\mathbf{N}_{7}$, ${}^{14}_{6}\mathbf{C}_{8}$)

Isomer = same isotope but with excited state (usually long-lived)

(e.g. ${}^{189}$Au, stable; ${}^{189m}$Au, half-life = 4 minutes)

Mirror nuclei are isobars (same A) with opposite numbers of protons and neutrons.

For example, ${}^{14}$C (Z=6, N=8) and ${}^{14}$O (Z=8, N=6) are mirror nuclei.

Abundance = relative percentage (by number) of isotope.

Photon is quantity of electromagnetic energy with a specific linear momentum.

The equations which applied to each particle moving with light speed, as follow:

$E=mc^2$ (photon as a particle "Einstein equation")

$E=h\nu=hc/\lambda$ (photon as a wave "plank equation")

$P=mc$ (photon as a particle)

$P=h/\lambda=h\nu/c$ (photon as a wave "Compton assumption")

**Units:**

Length: 1 angstrom = $10^{-10}$m = 1Å

1 fermi (or femtometer) = $10^{-15}$m = 1fm.

Energy: 1 electron volt (eV) = energy of electron accelerated through 1 volt electrical potential = 1.6 x $10^{-19}$J.

1u (atomic mass unit) = 931.502MeV/$c^2$ (where $^{12}$C has mass = 12.00000u)

$m_p$ = 938.280MeV/$c^2$    $m_n$= 939.573MeV/$c^2$    $m_e$ = 0.511MeV/$c^2$

Speed of light, c = 3x$10^8$m/s, Electron charge, e = 1.6x$10^{-19}$C,

Planck constant, h = 6.63x$10^{-34}$J.s, Avogadro's number, $N_a$ = 6.022x$10^{23}$mol$^{-1}$