BASIC CONCEPTS

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SOME INTRODUCTORY TERMINOLOGY

A nuclear species is characterized by the total amount of positive charge in the nucleus and by its total number of mass units.

$+Ze \rightarrow$ Net nuclear charge

$Z \rightarrow$ Atomic number

$e \rightarrow$ magnitude of the electronic charge

The fundamental positively charged particle in the nucleus is the proton. An electrically neutral atom therefore must contain Z negatively charged electrons. $m_p \cong 2000\ m_e$

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The mass number of a nuclear species, indicated by the symbol A, is the integer nearest to the ratio between the nuclear mass and the fundamental mass unit, defined so that the proton has a mass of nearly one unit.

The neutron is electrically neutral and has a mass about equal to the proton mass (actually about % 0.1 larger)

When we wish to indicate a specific nuclear species, or nuclide, we generally use the form

$$^{A}_{Z}X_{N}$$

SOME INTRODUCTORY TERMINOLOGY

where X is the chemical symbol and A = Z + N is the mass number.

The symbols for some nuclides are

$$ {}^{1}_{1}H_{0}\ ,\ {}^{238}_{92}U_{146}\ ,\ {}^{56}_{26}Fe_{30} $$

It is also not necessary to write N, since we can always find it from A-Z.

Neutrons and protons are the two members of the family of nucleons.

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Thus a nucleus of a mass number A contains A nucleons.

When talking of different nuclei we can refer to them as

- **Nuclide:** atom/nucleus with a specific N and Z.
- **Isotope:** Nuclei with the same number of protons (Z), but a different number of neutrons (N) and a different mass (A)
- **Isotone:** Nuclei with the same number of neutrons (N), but a different number of protons (Z) and a different mass (A)
- **Isobar:** Nuclides with the same mass number (number of nucleons) A, but a different number of protons (Z) and neutrons (N)
- **Isomers:** Nuclides with the same Z and A in different excited states

NUCLEAR PROPERTIES

Once we have identified a nuclide, we can then set about to measure its properties, among which are mass, Radius, relative abundance (for stable nuclides), decay modes and half-lives (for radioactive nuclides), reaction modes and cross sections, spin, magnetic dipole and electric quadrupole moments, and excited states.

Stable Nucleus - A nuclear system that does not undergo radioactive decay (ie. it is energetically unfavourable). This region of the nuclear chart is often called the Valley of Stability or Line of Stability.

(See Figure 1.1, Introductory Nuclear Physics, by Kenneth S. Krane)

NUCLEAR PROPERTIES

Radioactive Nucleus (or unstable) - A nucleus that is spontaneously able to decrease its total energy by emmitting ionizing radiation. This may result in a change in the total number of protons and neutrons.

Neutron-Rich Nucleus - A nucleus that has an excess of neutrons relative to the stable isotope for a given Z. This is to the right of the valley of stability.

Neutron-Deficient Nucleus (also: Proton-Rich) - A nucleus that has an excess of protons relative to the stable isotope for a given Z. This is to the left of the valley of stability.

UNITS AND DIMENSIONS

In nuclear physics we encounter lengths of the order of 10^{-15} m, which is one femtometer (fm).

The time scale of nuclear phenomena has a enormous range. Some nuclei break apart in times of the order of 10^{-20} s. Many nuclear reactions take place on this time scale, which is roughly the length of time that the reacting nuclei are within range of each other's nuclear force.

Electromagnetic (γ) decays of nuclei occur generally within lifetimes of the order of 10^{-9} s (nanosecond, ns) to 10^{-12} s (picosecond, ps), but many decays occur with much shorter or longer lifetimes. α and β decays occur with even longer lifetimes often minutes or hours, but sometimes thousands or even millions of years.

UNITS AND DIMENSIONS

Nuclear energies are conveniently measured in millions of electron-volts (MeV), where 1 eV = 1.602×10^{-19} J is the energy gained by a single unit of electronic charge when accelerated through a potential difference of one volt.

Typically β and γ decay energies are in the range of 1 MeV, and low-energy nuclear reactions take place with kinetic energies of order 10 MeV.

Nuclear masses are measured in terms of the unified atomic mass unit, u, defined such that the mass of an atom ^{12}C is exactly 12 u. Thus the nucleons have masses of approximately 1 u.

UNITS AND DIMENSIONS

On this scale, one mass unit

$$1\ u \quad = \quad \frac{1}{12} \cdot m(^{12}\mathrm{C}) \qquad\qquad 1\ u = 1.660 \times 10^{-27}\ \text{kg}$$

In analyzing nuclear decays and reactions, we generally work with mass energies rather than with the masses themselves. The conversion factor is

Recall: $E = mc^2$

- $m_p = 938.27\ \text{MeV}/c^2$
- $m_n = 939.56\ \text{MeV}/c^2$
- $m_e = 0.511\ \text{MeV}/c^2$

$$1\ u = 931.494\ \text{MeV}/c^2$$

REFERENCES

1. Introductory Nuclear Physics. Kenneth S. Krane

2. Fundamentals of Nuclear Physics. Atam. P. Arya