Redioactive Decay

Course: MPHYCC-13 Nuclear and Particle Physics
(M.Sc. Sem-III)

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Unit which I will start

Unit 4: Nuclear decay: (a) Fermi theory of β decay, allowed and forbidden transitions. Parity violation in β decay and Helicity of neutrino. (b) Radiative transitions in nuclei (γ-decay), Spontaneous decay, internal conversion, Mossbauer Effect

(Prerequisite: Quantum Physics; in particular, time-dependent perturbation theory, Angular momentum algebra, C. G. Coefficients)

Nuclear and Particle Physics in CSIR-UGC NET

Basic nuclear properties: size, shape and charge distribution, spin and parity. Binding energy, semi-empirical mass formula, liquid drop model. Nature of the nuclear force, form of nucleon-nucleon potential, charge-independence and charge-symmetry of nuclear forces. Deuteron problem. Evidence of shell structure, single-particle shell model, its validity and limitations. Rotational spectra. Elementary ideas of alpha, beta and gamma decays and their selection rules. Fission and fusion. Nuclear reactions, reaction mechanism, compound nuclei and direct reactions.

Classification of fundamental forces. Elementary particles and their quantum numbers (charge, spin, parity, isospin, strangeness, etc.). Gellmann-Nishijima formula. Quark model, baryons and mesons. C, P, and T invariance. Application of symmetry arguments to particle reactions. Parity non-conservation in weak interaction. Relativistic kinematics.

Reference Books

1. *Introductory Nuclear Physics* by **Kenneth S. Krane**

2. *Nuclear Physics* by **S. N. Ghoshal**

3. *Nuclear Physics* by **D. C. Tayal**

4. *Elements of Nuclear Physics* by **W. E. Burcham**

Basics Concepts in Nuclear Physics

- *In nuclear physics, we study about atomic nucleus and particles inside it and the interaction between these particles.*

- *Most of the mass of an atom is centred in the nucleus (In general, the nucleus contains more than 99.9% of the mass of the atom).*

- *To get an idea of the size of the nucleus, the diameter of the nucleus ranges from around 1.75 fm (1.75 x 10^{-15} m) for hydrogen to about 11.71 fm for uranium. While the diameter of hydrogen atom is 156 x 10^{-12} m (i.e. nucleus of hydrogen is about 26,634 times smaller than the atom itself) and uranium atomic diameter is 156 x 10^{-12} m (nucleus of uranium is 60,250 times smaller than uranium atom).*

- *Important terminology:*
  A given atom is specified by the number of - neutrons: N - protons: Z - electrons: there are Z electron in neutral atoms. In general, the atomic nuclei are denoted by the symbol:

$$ {}^{A}_{Z}X $$

where X represents the chemical symbol and A=Z+N is the mass number.
For example: ${}^{235}_{92}U$

- Nuclide: atom/nucleus with a specific N and Z.
- Isotope: nuclides with same Z.
- Isobar: nuclides with same mass number A.
- Isotone: nuclides with same N.
- Isomer: same nuclide (but different energy state).

- *A simple formula that links the nucleus radius to the number of nucleons is the empirical radius formula:*

$$ R = R_0 A^{1/3} $$

- *Units, dimension:*
  Energies in nuclear physics are measured in the power of the unit Electronvolt: 1eV = $1.6x10^{-19}$J (Definition: 1 electronvolt is basically the kinetic energy gained by an electron accelerated through a potential difference of 1 volt.). Nuclear energies are usually in the range of MeV (mega-electronvolt, or 10^6eV).
  Masses in energy unit: *To illustrate, lets consider the example of proton: we know that mass of a proton m=1.6726 x 10^{-27} kg, then from the Einstein famous mass-energy equivalence relation*

  $$E = mc^2$$
  $$= 1.6726 \times 10^{-27} \times (3 \times 10^8)^2 = 1.505\times10^{-10} \text{ Joule}$$
  $$1 \text{ Joule} = 1.6 \times 10^{-13} \text{ MeV}$$
  $$E= (1.505\times10^{-10} / 1.6 \times 10^{-13}) \text{ Mev} = 940.62\text{MeV}$$

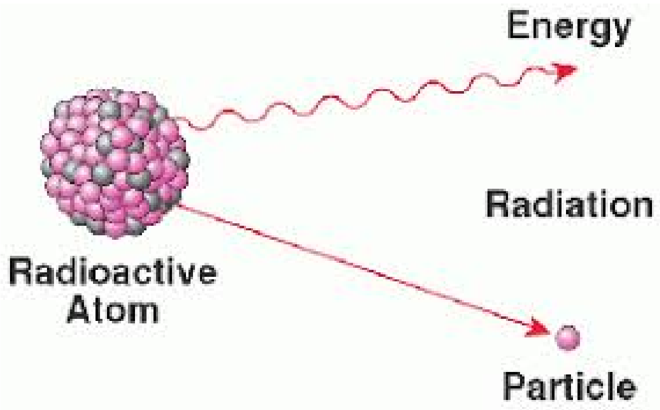
  Above is the approximate calculation.
  A more accurate calculation shows that the mass of the proton in energy units is m= 938.280 MeV / c^2.
  Similarly,
  Neutron mass: 938.573MeV/c^2
  Electron mass: 0.511MeV/c^2 .

- *Binding energy: Nuclear binding energy is the minimum energy that would be required to disassemble the nucleus of an atom into its component parts. Because of this binding energy mass of the a nucleus is always less than the total mass of all the neutrons and protons constituting the nucleus. This mass difference which, sometimes called mass defeat provides us the expression for the binding energy:*

$$B = \left[Zm_p + Nm_n - m_N(^AX)\right]c^2$$

Radioactive Decay

Radioactive decay is a spontaneous process in which an unstable atomic nucleus loses its energy by emitting subatomic particle or radiation. Radioactive decay is also known as nuclear decay, radioactivity, radioactive disintegration or nuclear disintegration. A material having unstable nuclei is known to be radioactive.

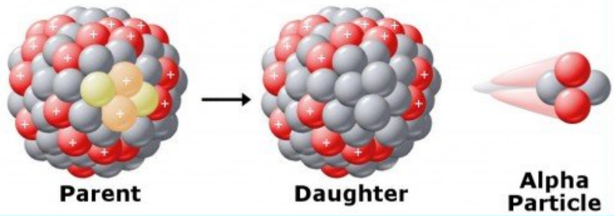
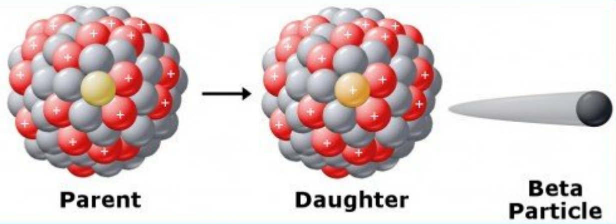
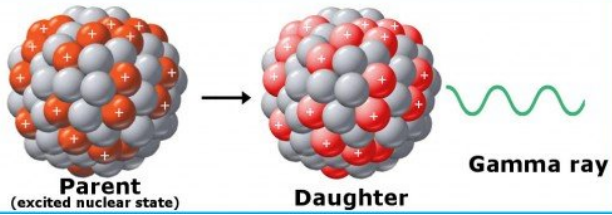


Commonly, there are three types of radioactive decay:

1. **Alpha Decay:** In this decay, the nucleus ejects an alpha particle (helium nucleus).

2. **Beta Decay:** The decay involves the ejection of an electron/positron and an antineutrino/neutrino from the nucleus.

3. **Gamma Decay:** During this decay, the nucleus emits gamma-photon. In general, in gamma decay, a radioactive nucleus first decays by the emission of an alpha or beta particle. The resulted daughter nucleus is usually left in an excited state and then it decays to a lower energy state by emitting a gamma ray photon.

Decay Type	Generic Equation	Model
Alpha decay	${}^{A}_{Z}X \longrightarrow {}^{A-4}_{Z-2}X' + {}^{4}_{2}\alpha$	
Beta decay	${}^{A}_{Z}X \longrightarrow {}^{A}_{Z+1}X' + {}^{0}_{-1}\beta$	
Gamma emmission	${}^{A}_{Z}X^{*} \xrightarrow{\text{Relaxation}} {}^{A}_{Z}X' + {}^{0}_{0}\gamma$	

Thanks for the attention!