Nucleus and its properties

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Radius

The nucleus contains protons and neutrons.When the no.of protons and neutrons increases ,the volume of the nucleus also increases

The volume of a nucleus is directly proportional to the mass number A

$4/3\pi R^3 \propto A$

$R^3 \propto A$ or $R \propto A^{1/3}$

$R=R_0A^{1/3}$

The value of $R_0=1.2 \times 10^{-15}m=1.2fm$

Density

Density of nucleus is an enormous value

The densities of nuclei are comparable to the densities of neutron stars

Example:Density of carbon nucleus($_6c^{12}$)

Atomic mass of =12u

$R=R_0A^{1/3}=1.2 \times 10^{-15} \times 12^{1/3}=2.7 \times 10^{-15}=2.7fm$

Density=mass/volume   =m/(4/3πR^3)

Density,

$$\rho = \frac{m}{\frac{4}{3}\pi R^3} = \frac{12 \times 1.66054 \times 10^{-27}}{\frac{4}{3} \times 3.14 \times (2.7 \times 10^{-15})^3} = 2.4 \times 10^{17}\, kg / m^3$$

Spin angular momentum

Spin angular momentum,

$S = \sqrt{s(s+1)}$ ħ,where s is the spin quantum number.

Protons and neutrons,like electrons are fermions with spin quantum number=½

∴S= $\frac{\sqrt{3}}{2}$ħ where ħ $= \frac{h}{2\pi}$

h=6.626 x 10^{-34}Js

ħ=1.054 x 10^{-34}Js

MAGNETI

↓ $\vec{M}$

equivalent to a tiny current loop and there produce a magnetic effect.

Time taken for one revolution $t = \frac{2\pi r}{v}$

electric current, $I = \frac{e}{t} = \frac{ev}{2\pi r}$

Magnetic moment of current loop, $\mu_e = IA$

[Magnetic analogue of electric dipole moment $P = qd$]

Magnetic moment, $\mu_e = IA = \frac{ev}{2\pi r} \times \pi r^2$

$$\mu_e = \frac{evr}{2}$$

[$\because L = mvr$]

$$\mu_e = \frac{eL}{2m}$$

In vector form $\vec{\mu}_e = -\frac{e\vec{L}}{2m}$.

Here M is the magnetic moment due to the orbital motion of the electron.

Similarly due to the spin angular momentum Magnetic moment can be written as

$$\mu = \frac{eS}{2m} = \frac{e\sqrt{s(s+1)}\hbar}{2m}$$

$$\mu_e = \sqrt{s(s+1)}\,\frac{e\hbar}{2m_e} \quad \left[\because S = \sqrt{s(s+1)}\hbar,\ S_z = m_s\hbar\right]$$

$\frac{e\hbar}{2m_e}$ = Bohr magneton (μ_B)

In the case of nucleons,

$$\text{Magnetic moment } \mu = \frac{\sqrt{s(s+1)}\,e\hbar}{2m_p}$$

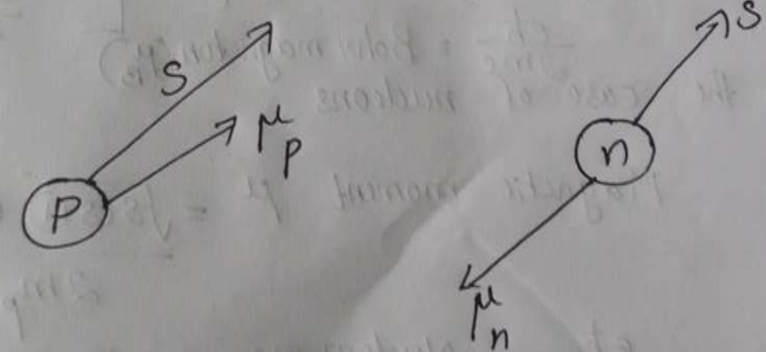
$\frac{e\hbar}{2m_p}$ = Nuclear magneton (μ_N)

$\mu_N <<< \mu_B$ because $m_e <<< m_p$

The actual value of spin magnetic moment of proton and neutron in the z direction is given by

$$\mu_{p,z} = +2.79 \frac{e\hbar}{2m_p} = +2.79 \mu_N$$

$$\mu_{n,z} = -1.191 \frac{e\hbar}{2m_p} = -1.91 \mu_N$$



Why neutrons have magnetic moment?

It arises from the presence of seperate layers of positive and negative charges within the neutron.Although the neutron contain equal amount of positive and negative charges,a spin magnetic moment could arise if these charges are not uniformly distributed.

Magnetic potential energy

Magnetic potential energy $Um=-\mu_z.B$

This energy is negative when μ_z is in the same direction of B(spin up).

And positive when $\mu_z$is in the opposite direction of B(spin down).

Nuclear Magnetic Resonance

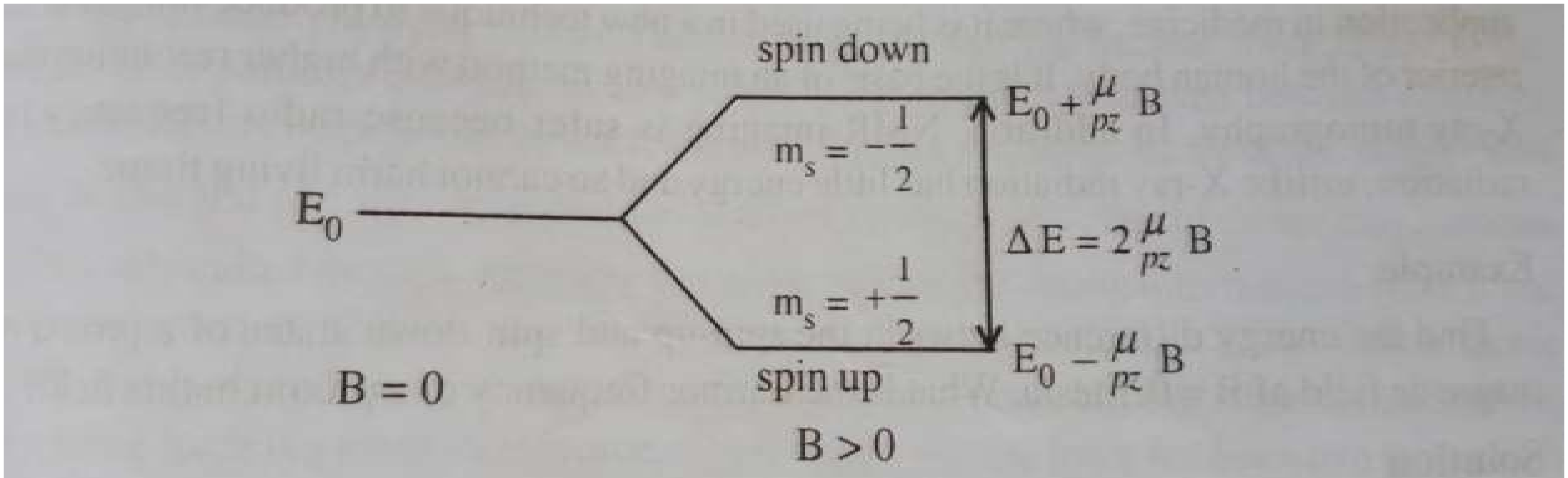


Fig. 4.2 The energy levels of a proton in a magnetic field are split into spin-up (spin parallel to B) and spin-down (spin antiparallel to B) sub levels

The energy difference between the sub levels is $\Delta E=2\mu_{pz}B$

A photon with this energy will be emitted when a proton in the upper state emitted to lower state by changing the spin.

A proton in the lower state can be raised to upperstate by absorbing a photon of this energy.

The photon frequency υ_L that corresponds to ΔE is called Larmour frequency

$\upsilon_L=\Delta E/h \quad =2\mu_{pz}B/h$

If we put a sample of some substance that contains nuclei with spins of ½ in a magnetic field B.The spins of most of these nuclei will become aligned parallel to B (spin up)because this is the lowest energy state.

If we supply electromagnetic radiation at the Larmour frequency υ_L to the sample,the nuclei will get right amount of energy to flip their spins to the higher state (spin down).

This phenomenon is called Nuclear Magnetic Resonance(NMR).

Nuclaer magnetic resonance can be attained in two ways

- Varying applied Magnetic field(B),keeping υ_L constant.
- Varying υ_L ,keeping applied Magnetic field(B)constant.

NMR occurs usually in the radiofrequency region.

Applications of NMR

- It is the most useful way to find nuclear magnetic moments
- In Chemistry,to understand the details of chemical structures and reactions.(NMR Spectroscopy)
- In Medicine,to produce the images of interior of the human body.

MRI scanning is safer than X ray scanning because,in MRI scanning, radiowaves are used which have little energy than X rays and so cannot harm living tissues.

THANK YOU...