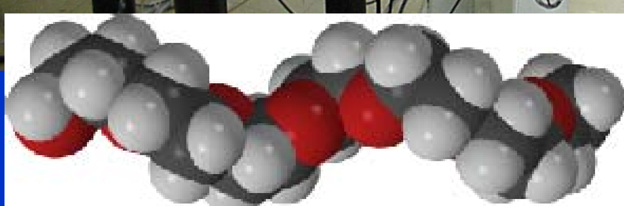
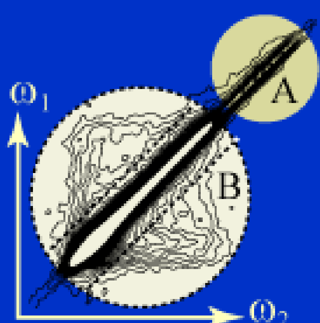
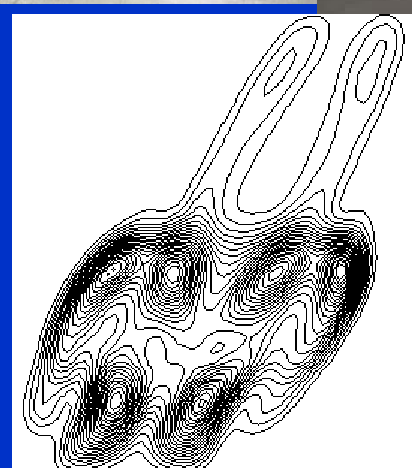
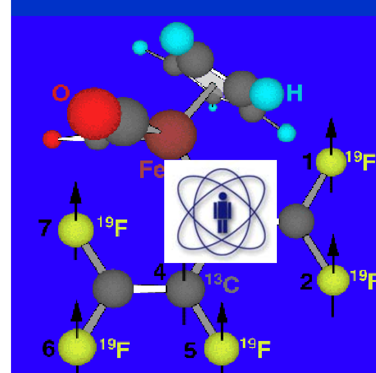
Ressonância Magnética Nuclear (RMN)

LEAR USP









História da Ressonância Magnética

Nobel em Física...

The Nobel Prize in Physics 1943

"for his contribution to the development of the molecular ray method and his discovery of the magnetic moment of the proton"

Otto Stern

USA

Carnegie Institute of Technology
Pittsburgh, PA, USA

b. 1888
(in Sorau, then Germany)
d. 1969

The Nobel Prize in Physics 1944

"for his resonance method for recording the magnetic properties of atomic nuclei"

Isidor Isaac Rabi

USA

Columbia University
New York, NY, USA

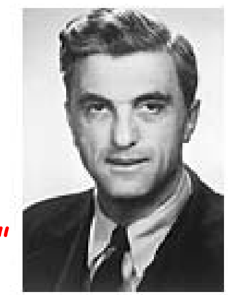
b. 1898
(in Rymanow, then Austria-Hungary)
d. 1988

← Feixes atômicos

Amostras "normais" →

The Nobel Prize in Physics 1952

"for their development of new methods for nuclear magnetic precision measurements and discoveries in connection therewith"



Felix Bloch

1/2 of the prize

USA

Stanford University
Stanford, CA, USA

b. 1905
(in Zurich, Switzerland)
d. 1983

Edward Mills Purcell

1/2 of the prize

USA

Harvard University
Cambridge, MA, USA

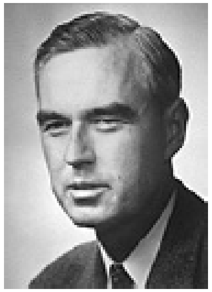
b. 1912
d. 1997

Nobel em Física

The Nobel Prize in Physics 1955

"for his discoveries concerning the fine structure of the hydrogen spectrum"

"for his precision determination of the magnetic moment of the electron"



Willis Eugene Lamb

1/2 of the prize

USA

Stanford University
Stanford, CA, USA

b. 1913

Polykarp Kusch

1/2 of the prize

USA

Columbia University
New York, NY, USA

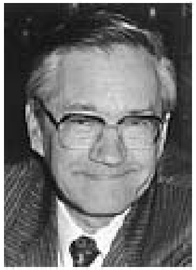
b. 1911
(in Blankenburg, then Germany)
d. 1993

?

Nobel em Química

The Nobel Prize in Chemistry 1991

"for his contributions to the development of the methodology of high resolution nuclear magnetic resonance (NMR) spectroscopy"



Richard R. Ernst

Switzerland

Eidgenössische Technische Hochschule (Swiss Federal Institute of Technology)
Zurich, Switzerland

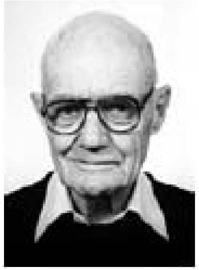
b. 1933

The Nobel Prize in Chemistry 2002

"for the development of methods for identification and structure analyses of biological macromolecules"

"for their development of soft desorption ionisation methods for mass spectrometric analyses of biological macromolecules"

"for his development of nuclear magnetic resonance spectroscopy for determining the three-dimensional structure of biological macromolecules in solution"



John B. Fenn

1/4 of the prize

USA

Virginia Commonwealth University
Richmond, VA, USA

b. 1917

Koichi Tanaka

1/4 of the prize

Japan

Shimadzu Corp.
Kyoto, Japan

b. 1959

Kurt Wüthrich

1/2 of the prize

Switzerland

Eidgenössische Technische Hochschule (Swiss Federal Institute of Technology)
Zurich, Switzerland;
The Scripps Research Institute
La Jolla, CA, USA

b. 1938

Nobel em Medicina

The Nobel Prize in Physiology or Medicine 2003

"for their discoveries concerning magnetic resonance imaging"

Paul C. Lauterbur
1/2 of the prize
USA

University of Illinois
Urbana, IL, USA

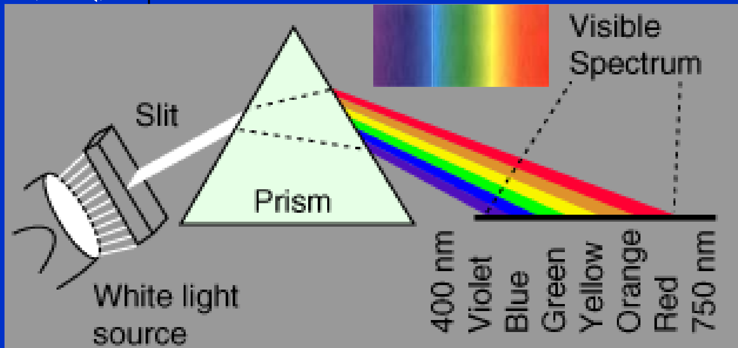
b. 1929

Sir Peter Mansfield
1/2 of the prize
United Kingdom

University of Nottingham,
School of Physics and Astronomy
Nottingham, United Kingdom

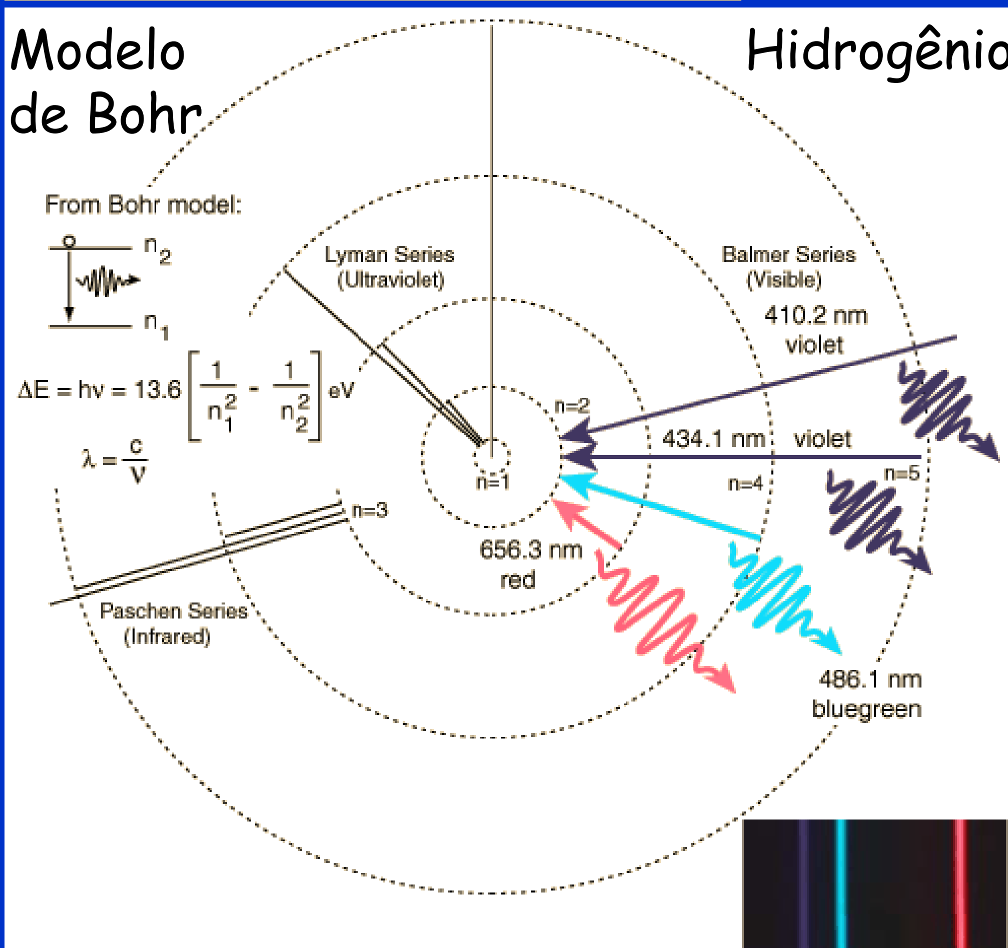
b. 1933

Física Moderna: Spin eletrônico

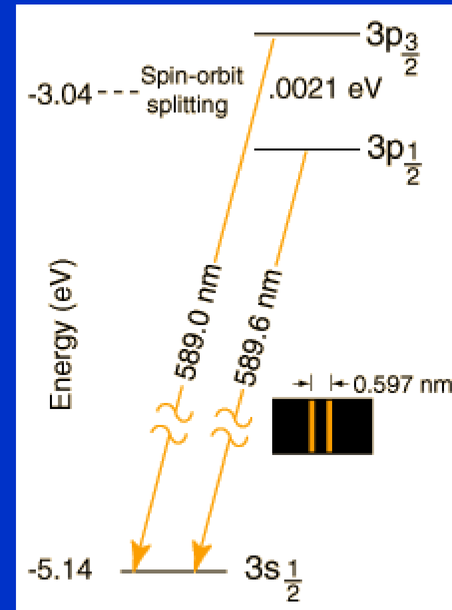


Modelo de Bohr

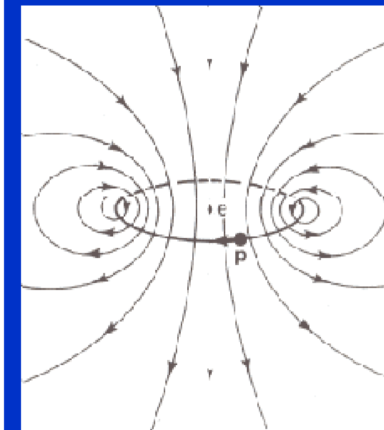
Hidrogênio

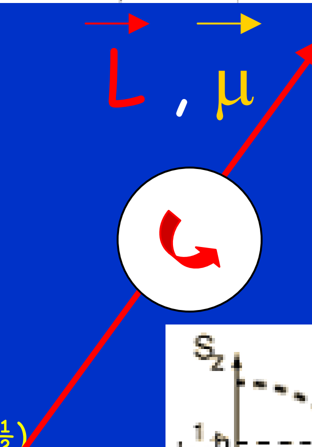


Átomo de Sódio:



Spin-órbita



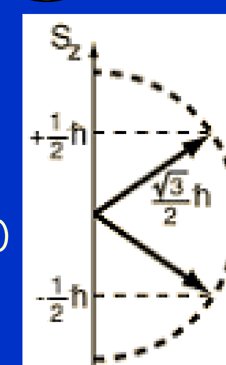


- *W. Pauli* (1924) - Nobel 45
  - *S. Goudsmit* e *G. Uhlenbeck* (1925)
    - -> spin 1/2
    - -> $|s| = (3/4)^{1/2}\,\hbar$
    - -> $s_z = \pm\hbar/2 = m_s\hbar \; (m_s = \pm \frac{1}{2})$
- *P. Kusch* (1925) - Nobel 55

-> $\mu_{e,z} = \pm (e/m_e)\hbar/2 = \gamma\, s_z = \gamma\,\hbar\, m_s \; (m_s = \pm \frac{1}{2})$

- *P.A.M. Dirac* (1928) - Nobel 33

  Eq. de onda relativística



$\mu_z = \gamma\,\hbar\, I_z \; (I_z = \pm \frac{1}{2})$

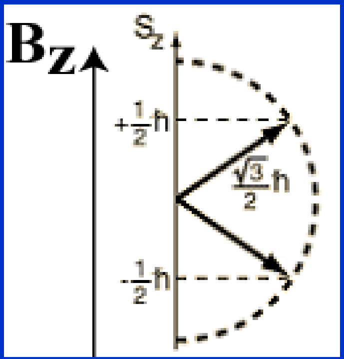
Intrinsic Spin of the Electron

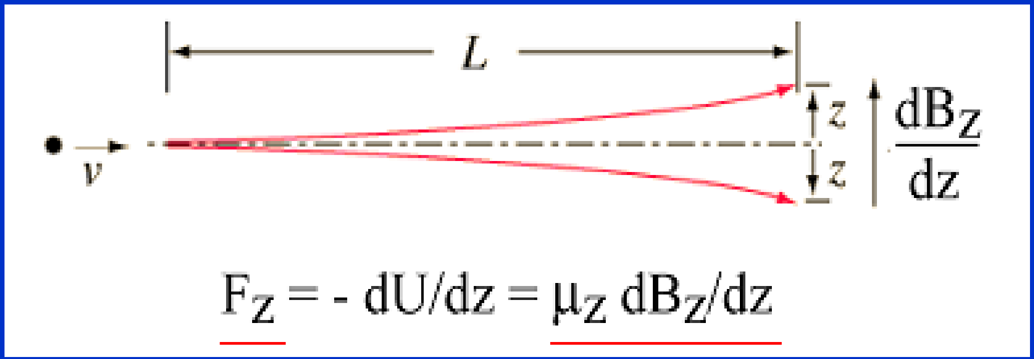
It was a little over fifty years ago that George Uhlenbeck and I introduced the concept of spin. . . . It is therefore not surprising that most young physicists do not know that spin had to be introduced. They think that it was revealed in Genesis or perhaps postulated by Sir Isaac Newton, which most young physicists consider to be about simultaneous.

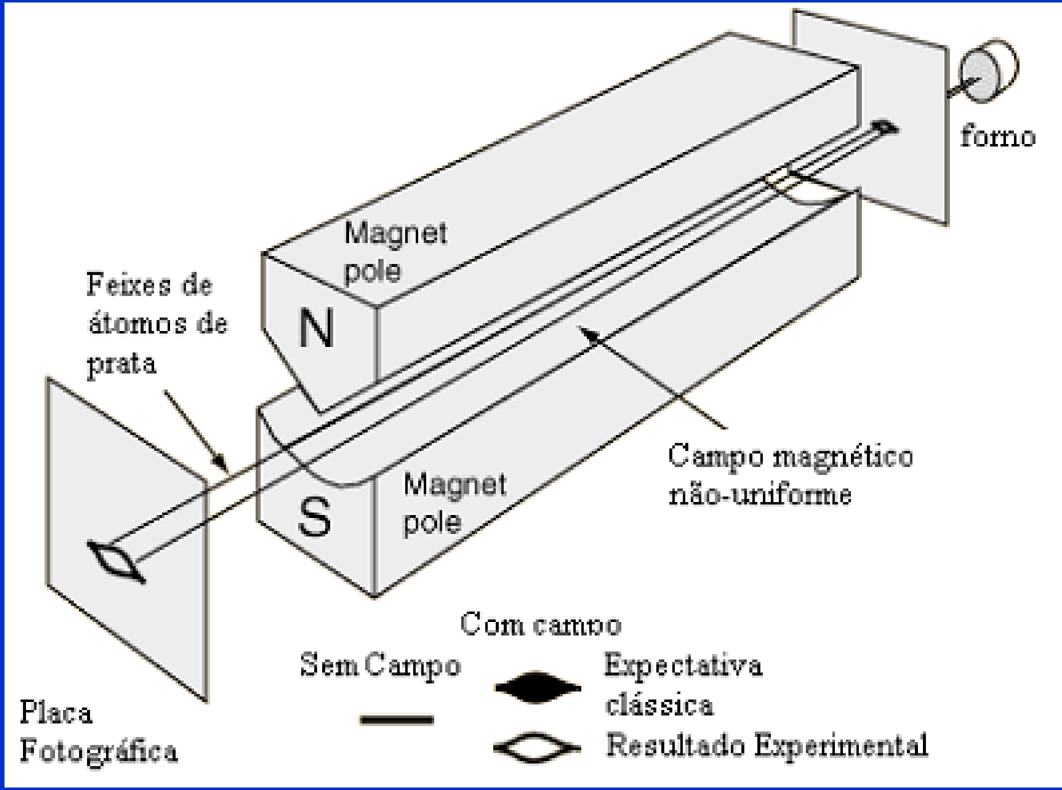
Samuel A. Goudsmit, address to the American Physical Society, February 1976

O Experimento de Stern-Gerlach

O. Stern and W. Gerlach, Zeitschr. f. Physik 9, 349 (1922) - Nobel 1943 (proton)
Carnegie Institute of Technology, Pittsburgh, PA, USA





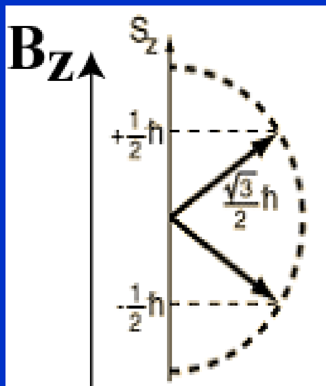


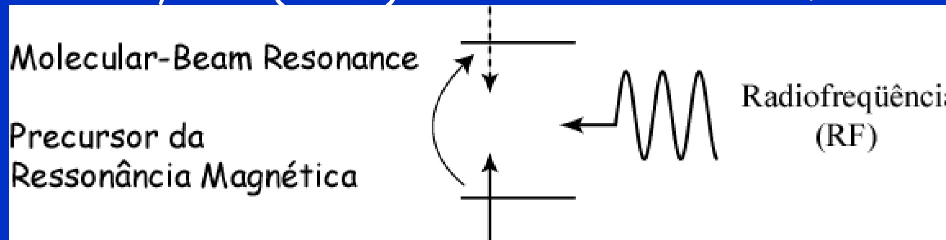
- Prata...
- Medidas de momentos magnéticos:

prótons* (s = 1/2) (Stern - Nobel/43)

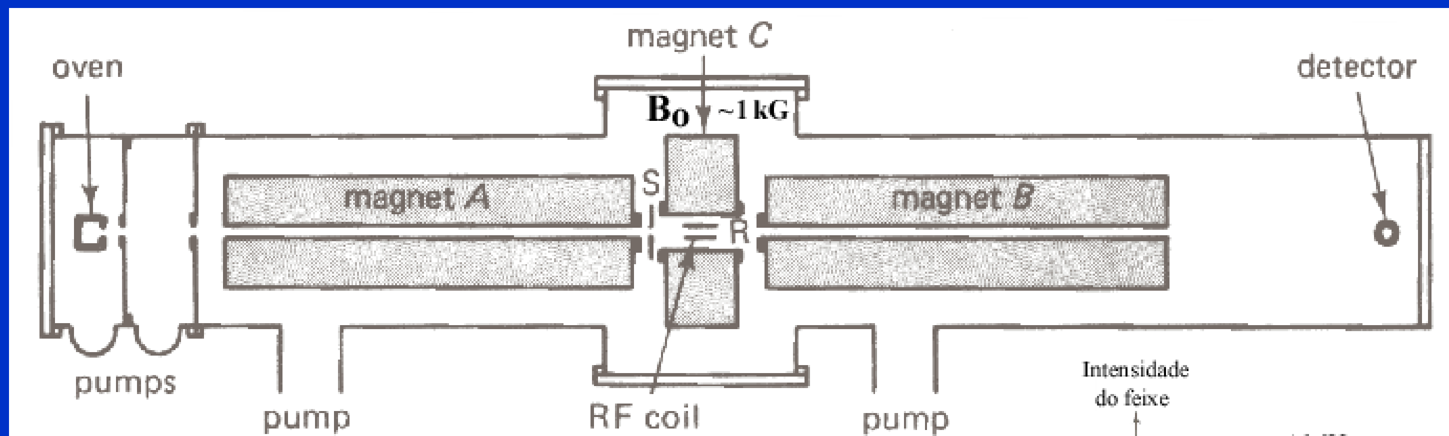
O experimento de Rabi

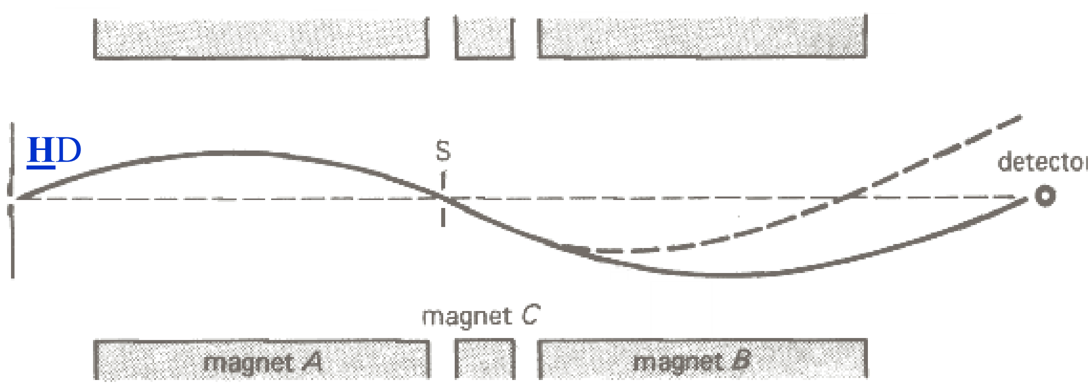
I. I. Rabi, Physical Review 55, 526 (1939) - Nobel 1944 - Columbia University - New York - USA



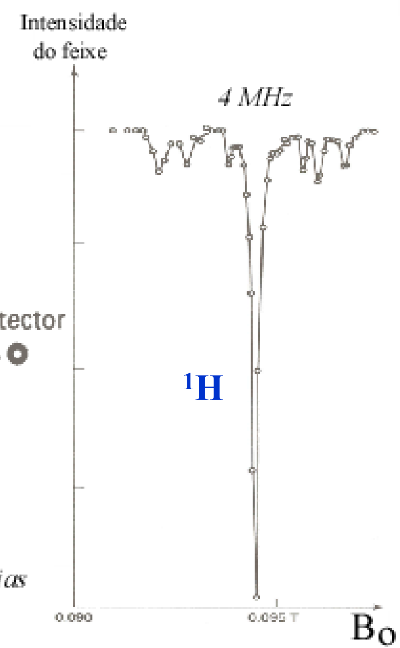


$$E = -\vec{\mu}.\vec{B} =$$
$$= -\gamma \hbar I_Z B_Z =$$
$$= \pm \frac{1}{2} \hbar \left(\gamma B_Z \right) =$$
$$= \pm \frac{1}{2} \hbar \omega_L$$





J.M.B Kellogg, I.I. Rabi, N.F. Ramsey, and J.R. Zacharias
Physical Review 56, 728 (1939)



O núcleo atômico

M = massa atômica *Z* = número atômico $^{M}X_{Z}$	Núcleons: *Z* prótons *N* (*M*-*Z*) nêutrons

$Exemplo: {}^{27}Al_{13}$	13 prótons 14 nêutrons

Prótons e nêutrons: momento angular intrínseco

$$\vec{s} \Rightarrow \pm \hbar/2$$

No núcleo ⇒ ambos também apresentam momento angular orbital

$$\vec{l} \Rightarrow -l\hbar, (-l+1)\hbar, \ldots, l\hbar$$

Núcleo: momento angular total = soma das contribuições individuais

SPIN :

$$\vec{I} \Rightarrow -I\hbar, (-I+1)\hbar, \ldots, I\hbar$$

Z prótons	*N nêutrons*	M	*Spin nuclear I*	*Exemplos*
Par	Par	Par	Zero	$^{12}C_6$ e $^{16}O_8$
Par	Ímpar	Ímpar	Semi-inteiro	$^{13}C_6$ e $^{17}O_8$
Ímpar	Par	Ímpar	Semi-inteiro	$^{19}F_9$ e $^{31}P_{15}$
Ímpar	Ímpar	Par	Inteiro	$^{2}H_1$ e $^{14}N_7$

Modelo de camadas - determinação do spin nuclear

Núcleo	*Z*	*N*	*Níveis ocupados*	*I*
	Prot.	Neut.		
^{13}C	6		$(1s_{1/2})^2\ (1p_{3/2})^4$	1/2
		7	$(1s_{1/2})^2\ (1p_{3/2})^4\ (1p_{1/2})^1$	
^{14}N	7		$(1s_{1/2})^2\ (1p_{3/2})^4\ (1p_{1/2})^1$	1
		7	$(1s_{1/2})_2\ (1p_{3/2})^4\ (1p_{1/2})^1$	
^{27}Al	13		$(1s_{1/2})^2\ (1p_{3/2})^4\ (1p_{1/2})^2\ (1d_{5/2})^5$	5/2
		14	$(1s_{1/2})^2\ (1p_{3/2})^4\ (1p_{1/2})^2\ (1d_{5/2})^6$	
^{29}Si	15		$(1s_{1/2})^2\ (1p_{3/2})^4\ (1p_{1/2})^2\ (1d_{5/2})^6\ (1s_{1/2})^1$	1/2
		14	$(1s_{1/2})^2\ (1p_{3/2})^4\ (1p_{1/2})^2\ (1d_{5/2})^6$	

Propriedades do núcleo atômico

Momento Magnético Nuclear: $\vec{\mu} = \gamma \hbar \vec{I} \quad \Rightarrow \quad |\vec{\mu}| = \gamma \hbar \sqrt{I(I+1)}$

$\gamma \rightarrow$ Fator giromagnético

Momento de Quadrupolo Elétrico Nuclear:

Spin = 1/2 ^{1}H, ^{13}C, ^{19}F Q = 0	**Spin > 1/2** ^{23}Na (3/2) $Q = 1 \times 10^{-29}\ m^2$	**Spin > 1/2** ^{7}Li (3/2) $Q = -4 \times 10^{-26}\ m^2$