

Potencial $V(r)$ entre núcleo e elétron e os níveis de Energia possíveis $\Rightarrow E_n = -E_0/n^2$

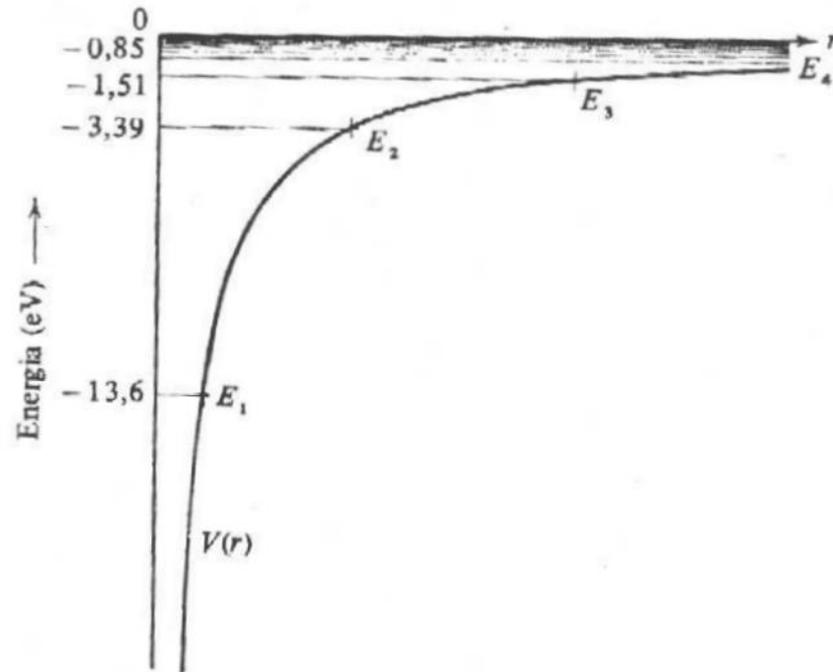


FIGURA 7-3. O potencial coulombiano $V(r)$ e seus autovalores E_n . Para valores grandes de n , os autovalores tornam-se muito pouco espaçados em energia porque E_n se aproxima de zero quando n tende a infinito. Observe que a interseção de $V(r)$ com E_n , que define a posição de um limite da região clássica permissível, se move para fora quando n aumenta. Não aparece na figura o contínuo de autovalores de energias positivas correspondentes aos estados não ligados.

Funções de onda do átomo de H

$$\Psi_{nlm}$$

Table 7.1 Some Hydrogen Atom Wave Functions

n	l	m_l	$R(r)$	$\Theta(\theta)$	$\Phi(\phi)$
1	0	0	$\frac{2}{a_0^{3/2}} e^{-r/a_0}$	$\frac{1}{\sqrt{2}}$	$\frac{1}{\sqrt{2\pi}}$
2	0	0	$\frac{1}{(2a_0)^{3/2}} \left(2 - \frac{r}{a_0}\right) e^{-r/2a_0}$	$\frac{1}{\sqrt{2}}$	$\frac{1}{\sqrt{2\pi}}$
2	1	0	$\frac{1}{\sqrt{3}(2a_0)^{3/2}} \frac{r}{a_0} e^{-r/2a_0}$	$\sqrt{\frac{3}{2}} \cos \theta$	$\frac{1}{\sqrt{2\pi}}$
2	1	± 1	$\frac{1}{\sqrt{3}(2a_0)^{3/2}} \frac{r}{a_0} e^{-r/2a_0}$	$\frac{\sqrt{3}}{2} \sin \theta$	$\frac{1}{\sqrt{2\pi}} e^{\pm i\phi}$

Números quânticos l e m_l

1

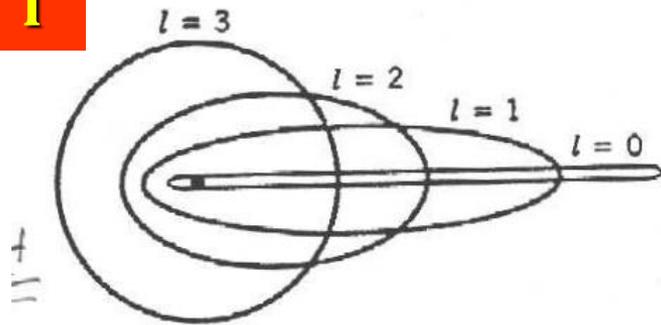


FIGURE 7.3 Electron orbits for $n = 4$. Note that (1) the average values of r are roughly the same; (2) in the orbits with smaller l -values, the electron spends more time *both* close to the nucleus and far away from the nucleus.

m_l

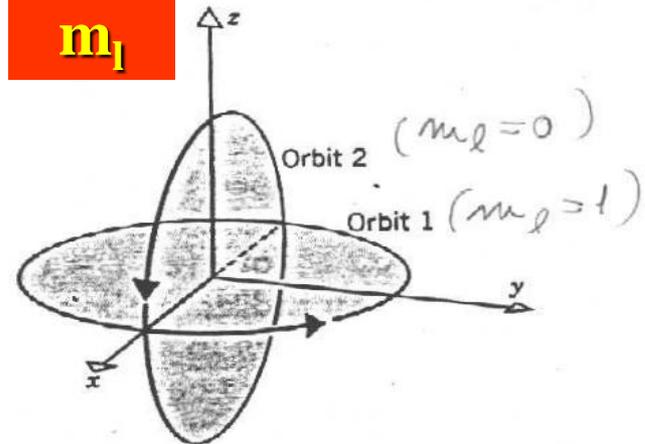


FIGURE 7.4 Two different orientations of the plane of an electron's orbit. Orbit 1 lies in the xy plane and represents $m_l = l$; orbit 2 lies in the xz plane and represents $m_l = 0$.

Espaço quantizado

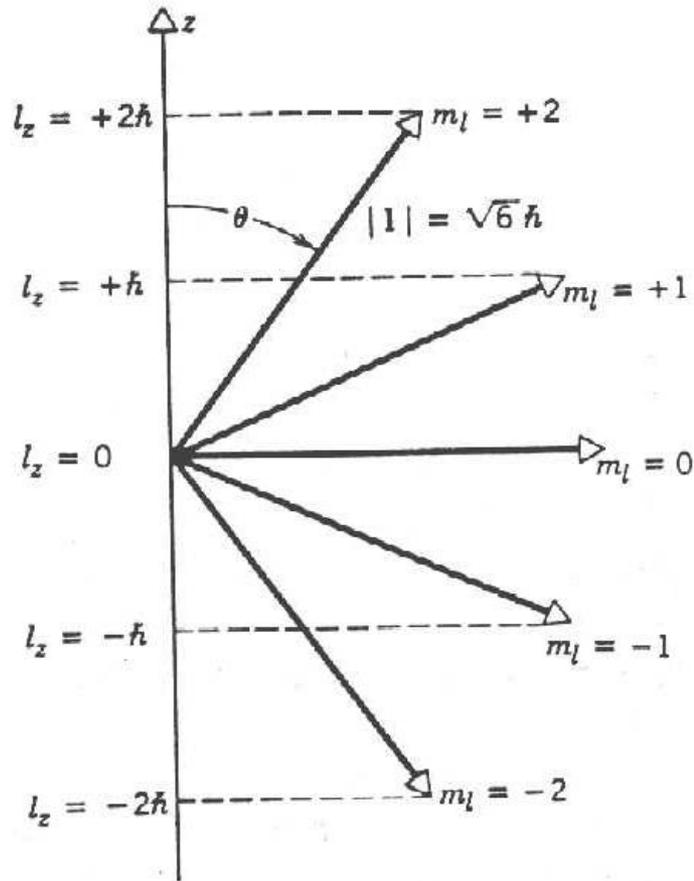


FIGURE 7.5 The orientations in space and z components of a vector with $l = 2$. There are five different possible orientations.

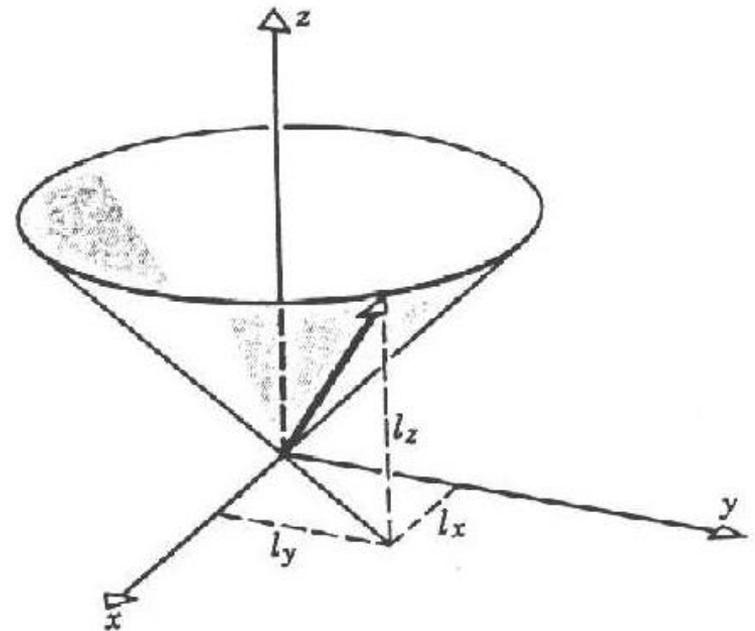


FIGURE 7.6 The vector l precesses rapidly about the z axis, so that l_z stays constant, but l_x and l_y are variable.

FIGURA 7-7. A variação com a distância ao núcleo da parte radial da função de onda do elétron no hidrogênio para diversos estados quânticos.

FIGURA 7-6. O modelo do átomo de hidrogênio de Bohr em um sistema de coordenadas polares esféricas.

órbita de Bohr do elétron

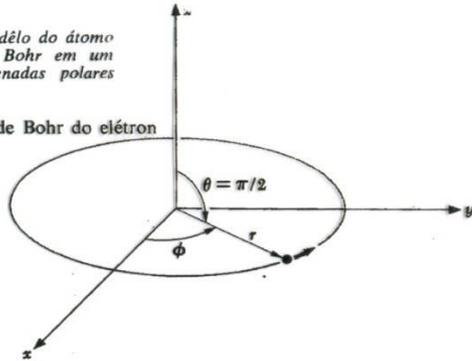


FIGURA 7-8. O volume de uma camada esférica.

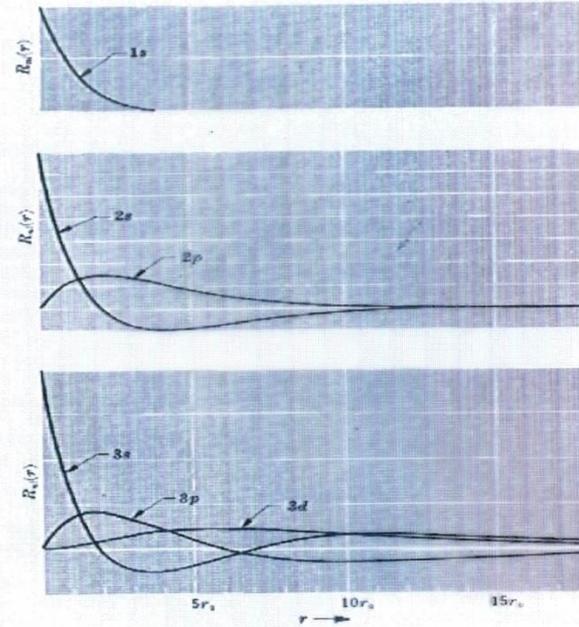
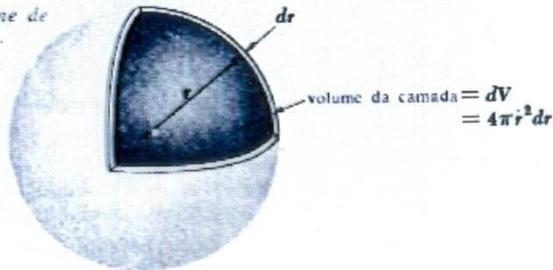
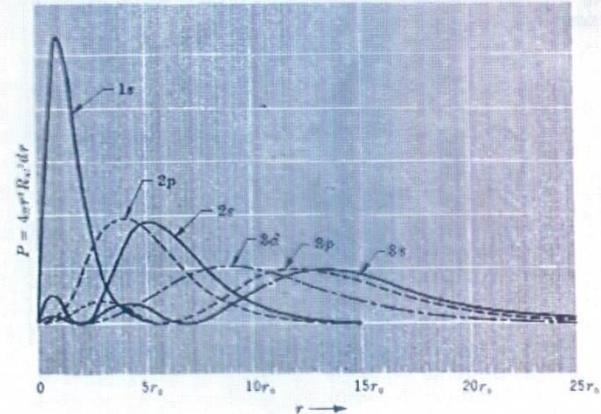


FIGURA 7-9. A probabilidade de se encontrar o elétron no átomo de hidrogênio a uma distância entre r e r + dr do núcleo, para os estados quânticos da Fig. 7-7.



LSu

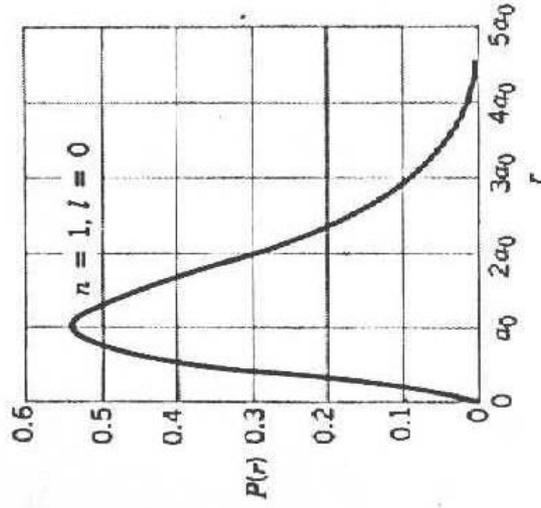
FUNÇÕES DE ONDAS

$R_{n,l}$

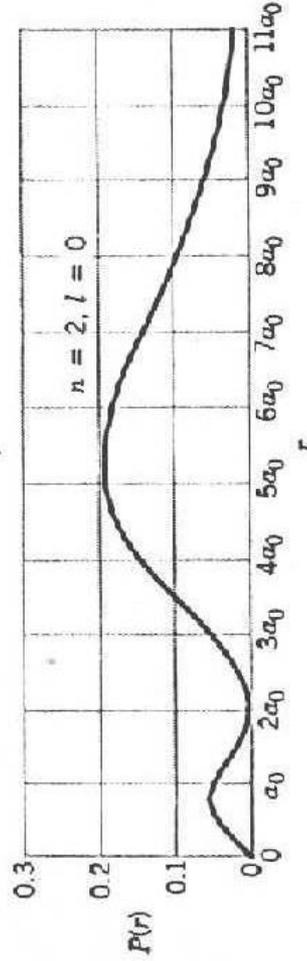
PROB.

$P(r)$

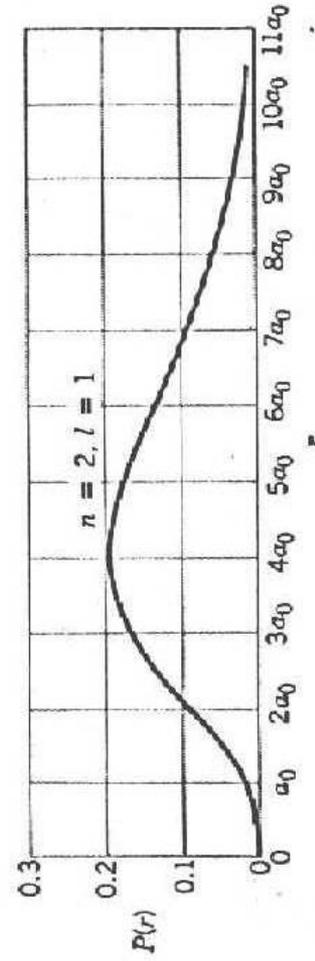
Densidades de probabilidade



1s



2s



2p

FIGURE 7.8 The radial probability density $P(r)$ for the three lowest states of hydrogen.

Densidades de probabilidade

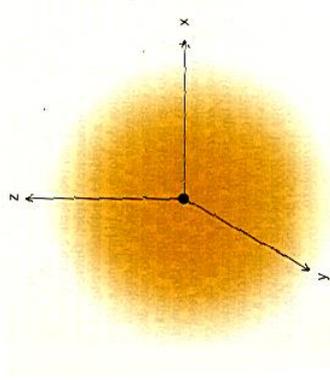


Figura 6-9. Nuvem eletrônica, concebida em seção atômica. A densidade de carga diminui rápida mas suavemente quando a distância do núcleo aumenta.

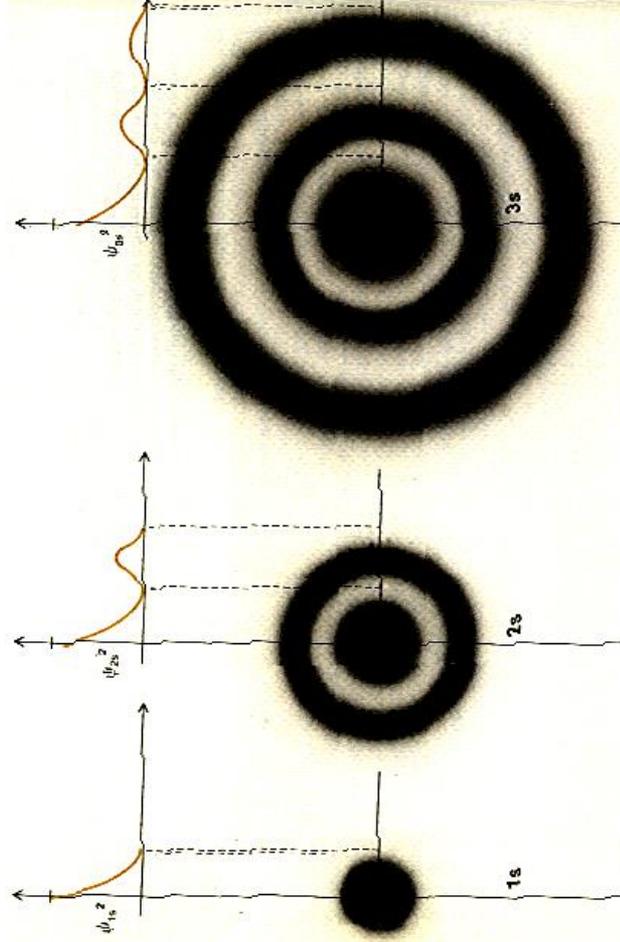


Figura 6-12. Nuvem de carga associada ao orbital s. Os esquemas mostram as seções transversais no plano do núcleo atômico.

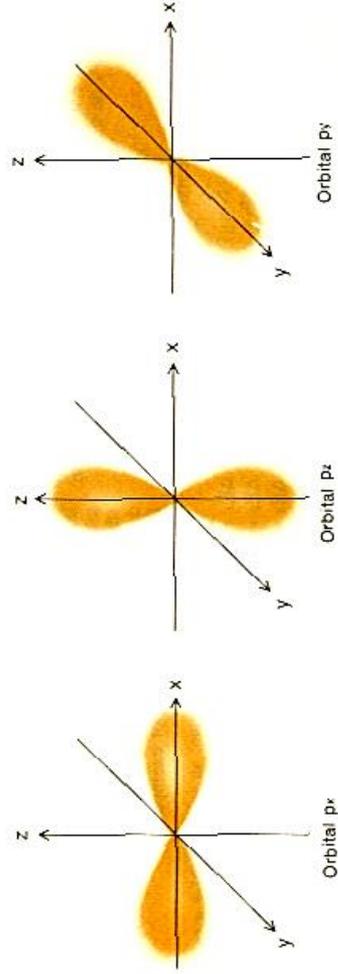
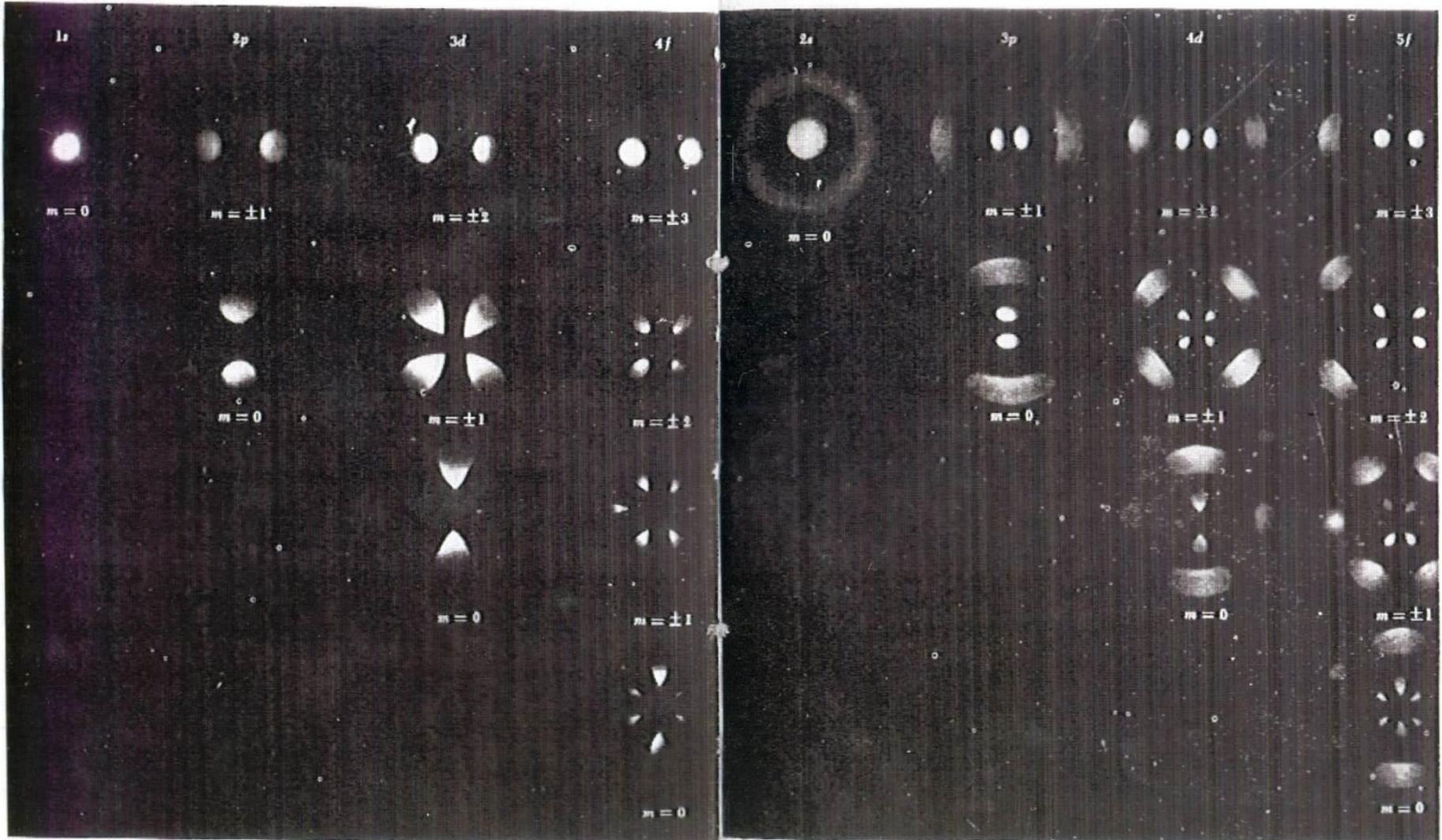


Figura 6-13. Nuvens eletrônicas associadas aos orbitais p. A densidade de carga é simétrica ao redor de um dos eixos cartesianos.

Densidades de probabilidade

FIGURA 7-10. Representação fotográfica da distribuição da densidade de probabilidade ψ^2 do elétron para vários estados de energia. Podemos considerar esta figura como um corte transversal das distribuições por um plano que contenha o eixo polar, o qual é, por sua vez, vertical, e se encontra no plano do papel. A escala varia de figura para figura.



Densidade de probabilidade $p/l=1$

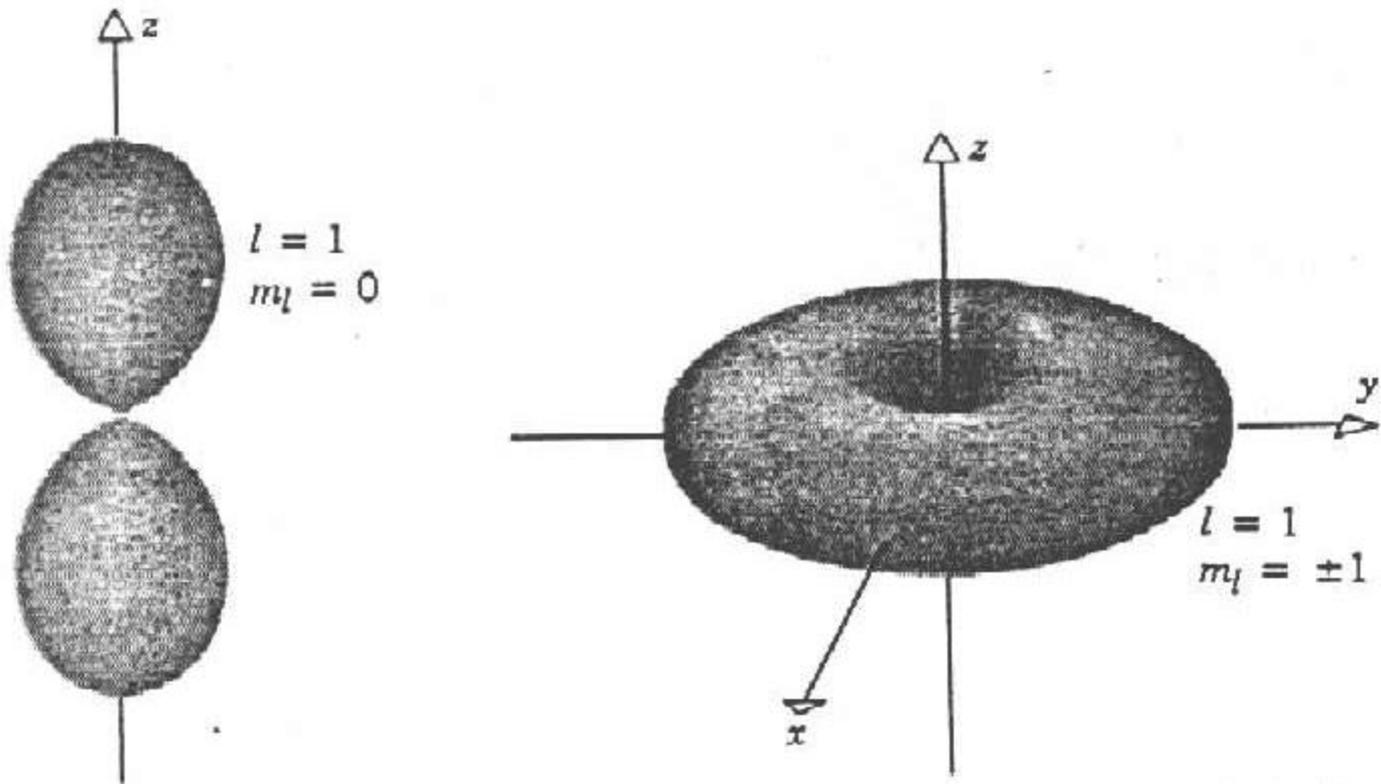


FIGURE 7.9 The angular dependence of the $l = 1$ probability density.

Densidades de probabilidade

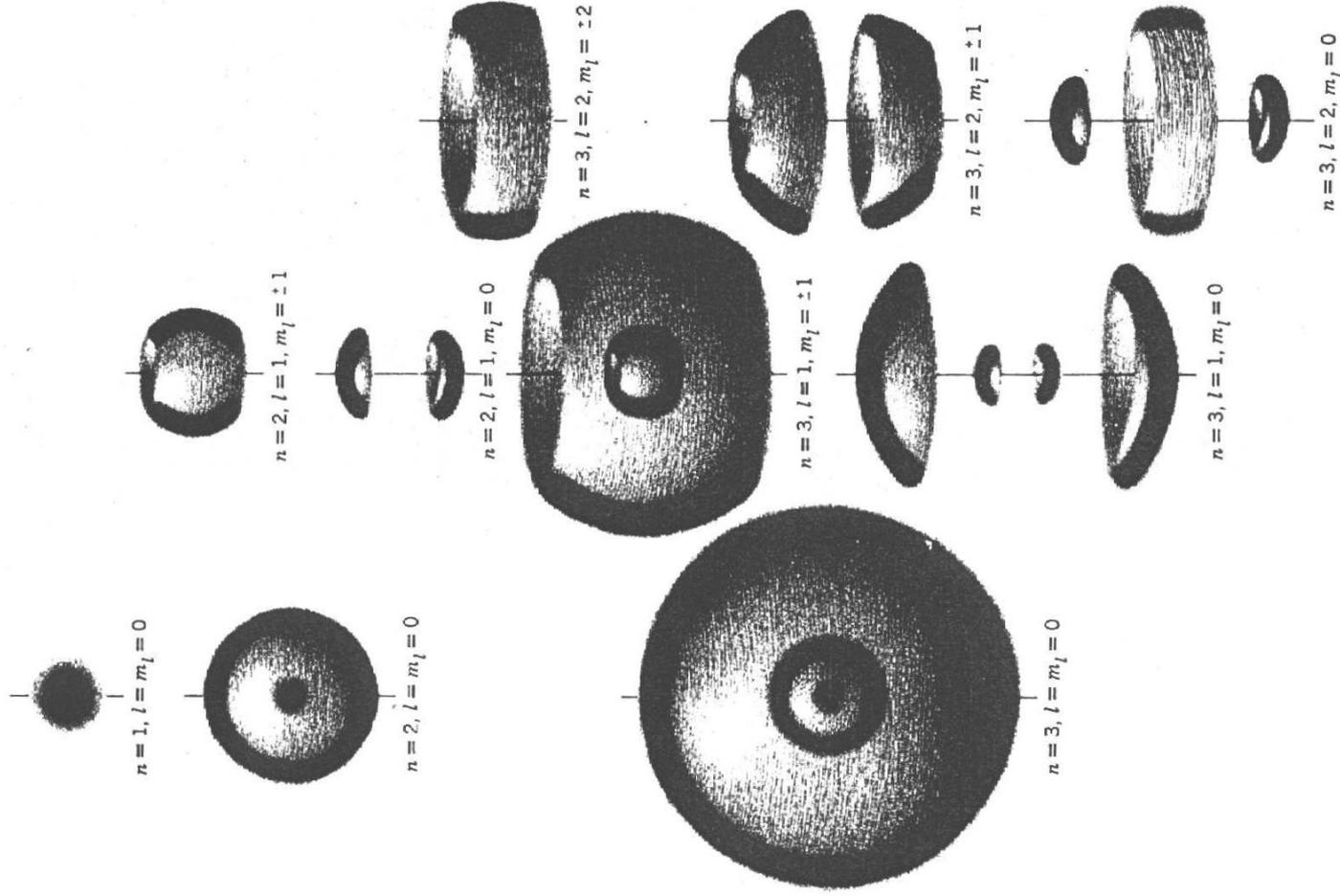


FIGURE 7.10 Representations of $|\psi|^2$ for different sets of quantum numbers. The intensity of each diagram at any point is proportional to the probability of locating an electron in a small volume element at that point. [Source: R. Eisberg and R. Resnick, *Quantum Physics of Atoms, Molecules, Solids, Nuclei, and Particles* (New York, Wiley, 1974)].

Momento magnético *spin* do elétron

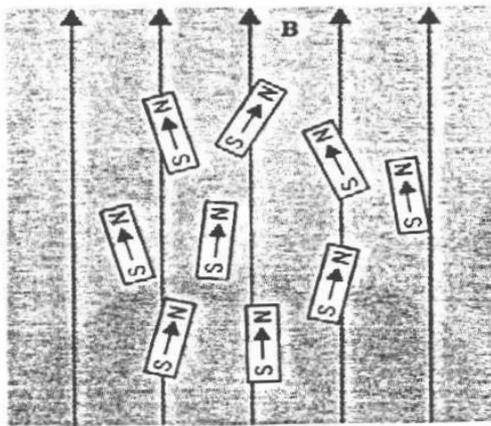
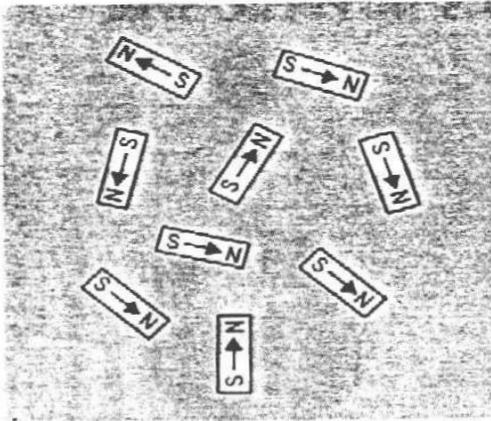
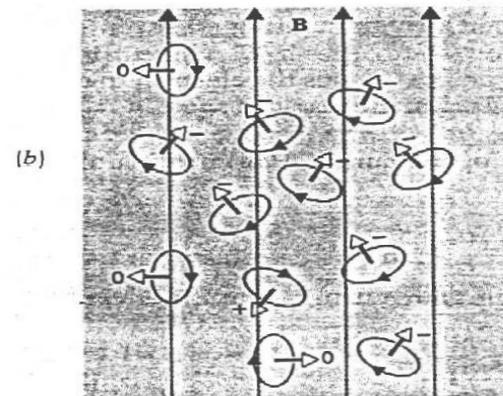
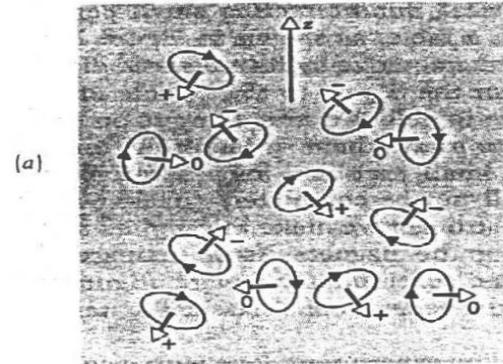


FIGURE 7.11 (a) A collection of small, noninteracting permanent magnets. The arrow shows the direction of the magnetic moments. (b) An applied magnetic field B rotates the magnetic moments into alignment with the field.



(a)

(b)

FIGURE 7.12 (a) A collection of non-interacting atomic magnetic moments. The arrow gives the direction of the magnetic moment. The z components of l are indicated as +, 0, and - for +1, 0, and -1. (Because of the minus sign in Equation (7.16), μ and l are in opposite directions.) Before the field is applied, there are equal numbers of atoms with each z component. (b) When the field is applied, the moments rotate around into alignment with the field, so that there are now many more atoms with $m_l = -1$.

Momento magnético *spin* do elétron

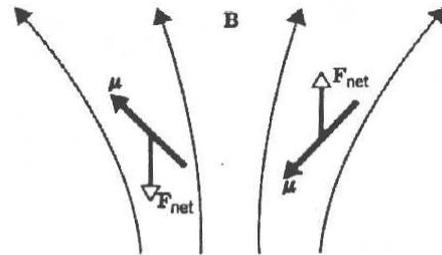


FIGURE 7.16 Two magnetic dipoles in a nonuniform magnetic field. Oppositely directed dipoles experience net forces in opposite directions.

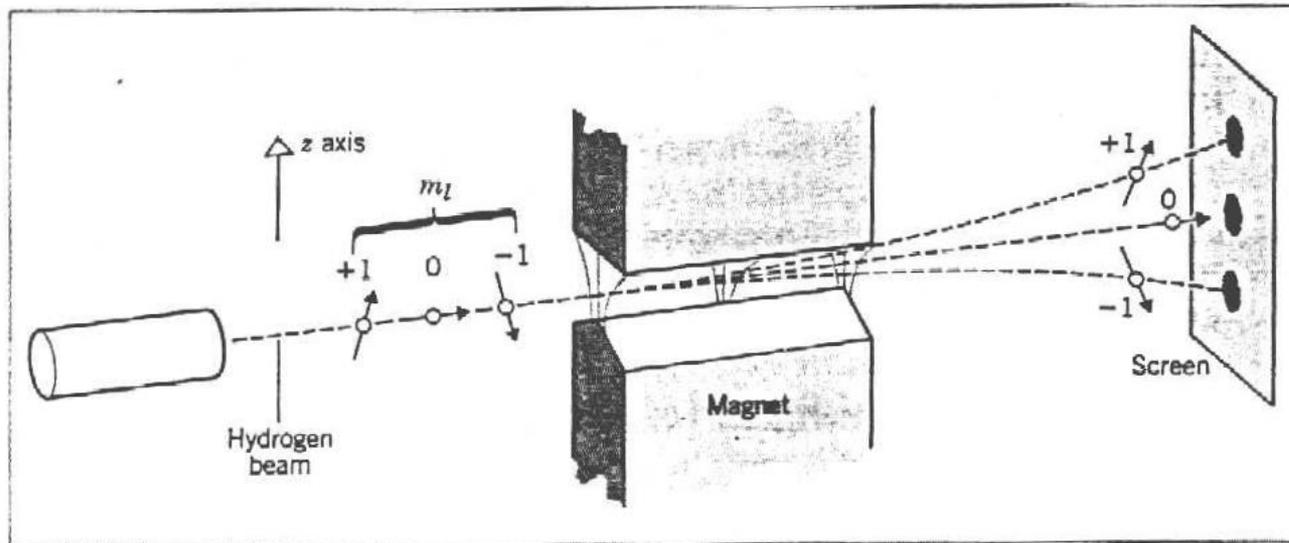


FIGURE 7.17 Schematic diagram of Stern-Gerlach experiment. A beam of atoms enters a region where there is a nonuniform magnetic field. Atoms with their magnetic dipole moments in opposite directions experience forces in opposite directions.

Momento magnético *spin* do elétron

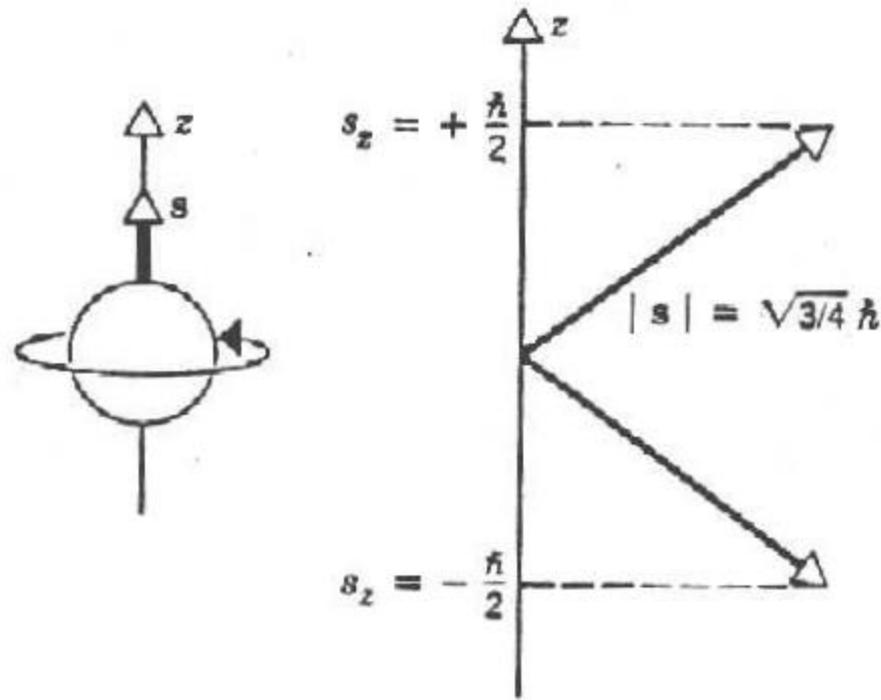


FIGURE 7.18 The spin angular momentum of an electron and the spatial orientation of the spin angular momentum vector.

Regras de seleção p/ transições permitidas

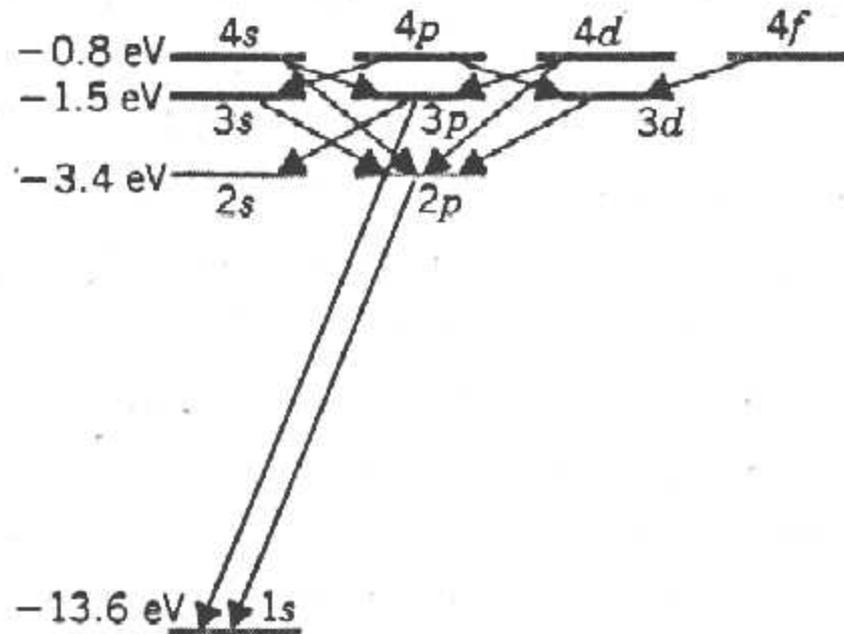


FIGURE 7.19 A partial energy level diagram of hydrogen, showing the spectroscopic notation of the levels and the transitions that satisfy the $\Delta l = \pm 1$ selection rule.

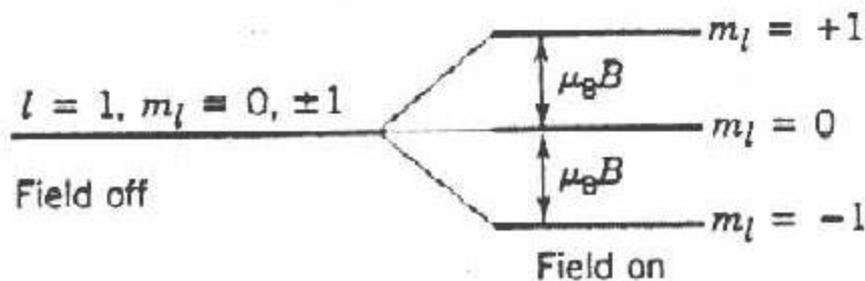


FIGURE 7.20 The Zeeman splitting of an $l = 1$ level in an external magnetic field. (The effects of the electron's spin angular momentum are ignored.) The energy in a magnetic field is different for different values of m_l .

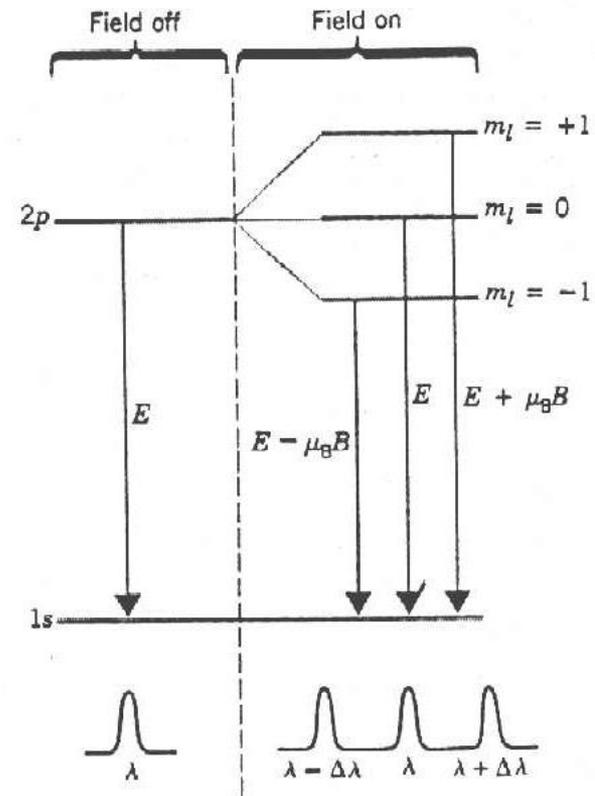
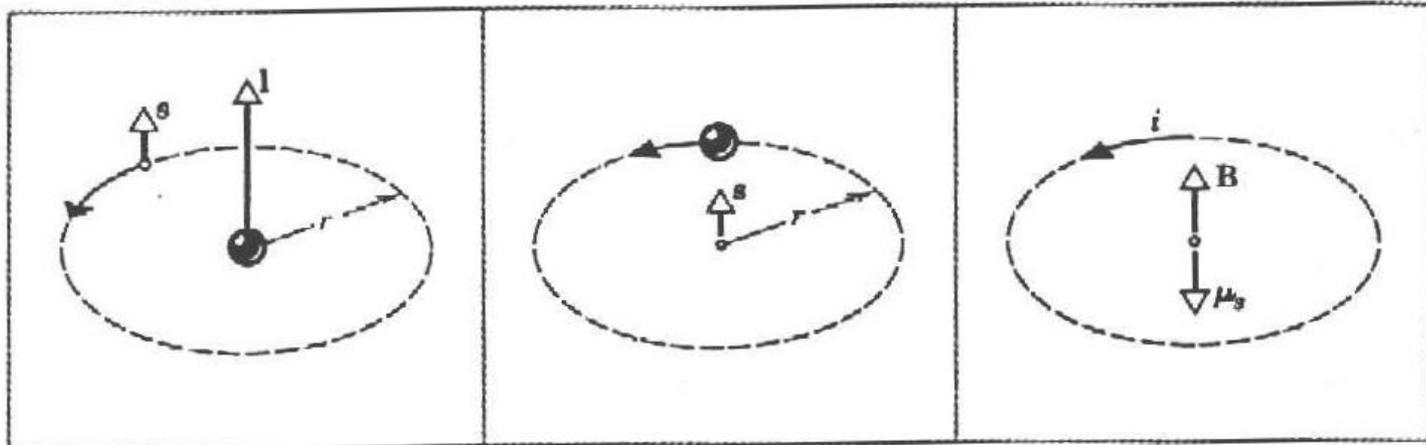


FIGURE 7.21 The normal Zeeman effect. When the field is turned on, the single wavelength λ becomes three separate wavelengths.



(a)

(b)

(c)

FIGURE 7.22 (a) An electron circulates about the nucleus with orbital angular momentum \mathbf{l} . The spin of the electron is parallel to \mathbf{l} . (b) From the point of view of the electron, the proton circulates as shown. (c) The apparently circulating proton is represented by the current i and causes a magnetic field \mathbf{B} at the electron. The spin magnetic moment of the electron is opposite to its spin angular momentum.