$$i\hbar \frac{\partial \psi(\vec{r},t)}{\partial t} = \left[-\frac{\hbar^2}{2m} - \frac{Ze^2}{r} - \vec{\mu}\cdot\vec{B} + \xi(r)\,\vec{S}\cdot\vec{L} \right] \psi(\vec{r},t)$$

MORE CHAPTER 7, #2

Normal and anomalous Zeeman effects :-

The Zeeman Effect

As we mentioned in Chapter 3, the splitting of spectral lines when an atom is placed in an external magnetic field was looked for by Faraday, predicted on the basis of classical theory by Lorentz, and first observed by Zeeman,[17] for whom the effect is now named.

In quantum mechanics, a shift in the frequency and wavelength of a spectral line implies a shift in the energy level of one or both of the states involved in the transition. The Zeeman effect that occurs for spectral lines resulting from a transition between *singlet* states is traditionally called the *normal* effect, while that which occurs when the total spin of either the initial or final states, or both, is nonzero is called the *anomalous* effect.[18] There is no fundamental difference between the two, however, so we will generally not distinguish between them, save for one exception: the large value of the electron's magnetic moment complicates the explanation of the anomalous effect a bit, so we will discuss the Zeeman effect in transitions between singlet states first.

$S = 0$

Normal Zeeman Effect

$\left(|\vec{\mu}\cdot\vec{B}| > |\xi(r)\,\vec{S}\cdot\vec{L}| \right)$

$\vec{J} = \vec{L} + \vec{S}$, $\vec{S} \to$ zero

For singlet states, the spin is zero and the total angular momentum **J** is equal to the orbital angular momentum **L**. When placed in an external magnetic field, the energy of the atom changes because of the energy of its magnetic moment in the field, which is given by

$$\Delta E = -\mu \cdot \mathbf{B} = -\mu_z B \qquad \textbf{7-68}$$

$\mu = \frac{q}{2M} L$

where the z direction is defined by the direction of **B** (compare with Equation 7-54). Using Equation 7-45 for μ_z, we have $\mu_z = -m_\ell \mu_B = -m_\ell (e\hbar/2m_e)$, and

$$\Delta E = +m_\ell \frac{e\hbar}{2m_e} B = m_\ell \mu_B B \qquad \textbf{7-69}$$

Since there are $2\ell + 1$ values of m_ℓ, each energy level splits into $2\ell + 1$ levels. Figure 7-28 shows the splitting of the levels for the case of a transition between a state with $\ell = 2$ and one with $\ell = 1$. The selection rule $\Delta m_\ell = \pm 1$ restricts the number of possible lines to the nine shown.

Because of the uniform splitting of the levels, there are only three different transition energies: $E_0 + e\hbar B/2m_e$, E_0, and $E_0 - e\hbar B/2m_e$, corresponding to the transitions with $\Delta m_\ell = +1$, $\Delta m_\ell = 0$, *and* $\Delta m_\ell = -1$. We can see that

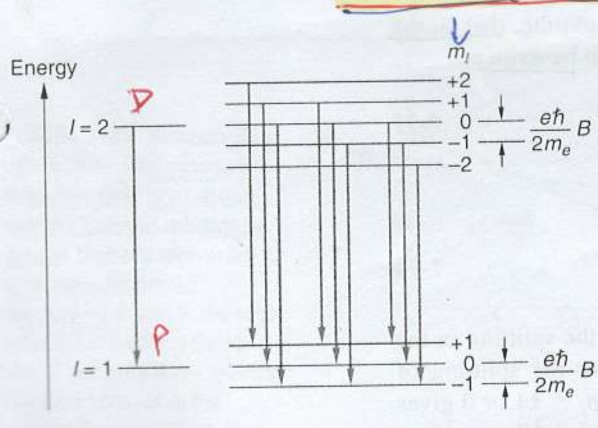
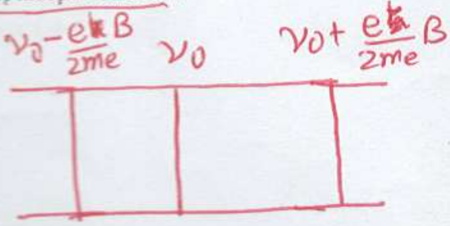


FIGURE 7-28 Energy-level splitting in the normal Zeeman effect for singlet levels $\ell = 2$ and $\ell = 1$. Each level is split into $2\ell + 1$ terms. The nine transitions consistent with the selection rule $\Delta m = 0, \pm 1$, give only three different energies because the energy difference between adjacent terms is $e\hbar B/2m_e$ independent of ℓ.



Selection Rule $\Delta m = 0, \pm 1$