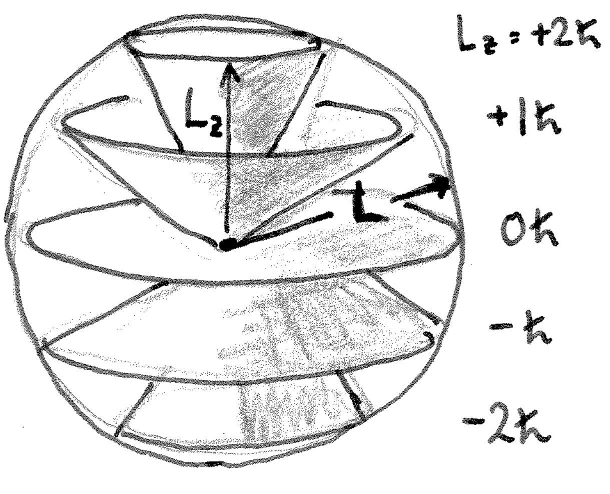
L15. ATOMIC STRUCTURE CONTINUED

Last time we learned that an electron wave in an atom is defined by a set of QUANTUM NUMBERS. In addition to the principal quantum number n, there are the orbital and magnetic quantum numbers ℓ & m_ℓ which determine

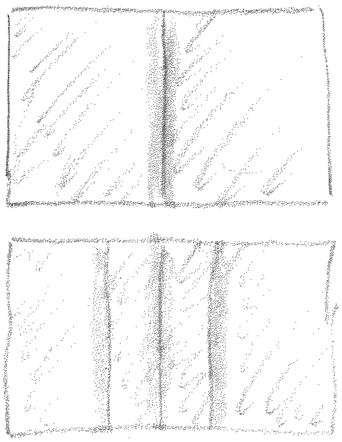
$$L = \hbar\sqrt{\ell(\ell+1)}$$ TOTAL ANGULAR MOMENTUM

$$L_z = m_\ell \hbar$$ z-component of angular momentum



Each of these states has the same energy – until a magnetic field is applied.

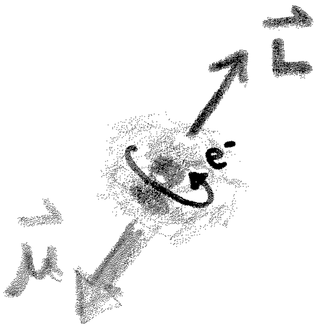
41.2 ZEEMAN EFFECT



Spectral lines <u>split</u> in a magnetic field.

WHY ?

Pieter Zeeman, 1896



Magnetic moment $\begin{cases} \vec{\mu} = I\vec{A} \\ U = -\vec{\mu}\cdot\vec{B} \end{cases}$

$$\mu = IA = \left(\frac{e}{t}\right)\pi r^2 = \frac{e}{(2\pi r/v)}\cdot\pi r^2$$

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

But $L = mvr$ $\Rightarrow$

$$\boxed{\mu = \frac{e}{2m}L}$$

When $L = \hbar$, as in the Bohr model $\mu = \mu_B$

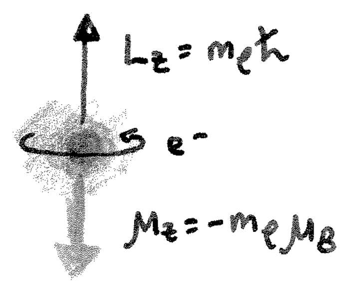
$$\boxed{\mu_B = \frac{e\hbar}{2m}}$$

BOHR MAGNETON

This is the basic unit of magnetic moment.

($\mu_B = 5.788 \times 10^{-5}\ \mathrm{eV/T}$.)

In a field along the z-axis

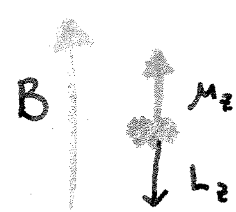


$$U = -\mu_z B$$

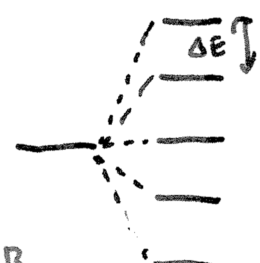
But $\mu_z = -e/2m\, L_z = -(e/2m_e)\, m_\ell \hbar = -\mu_B m_\ell$

So

$$\boxed{U = m_\ell(\mu_B B)}$$

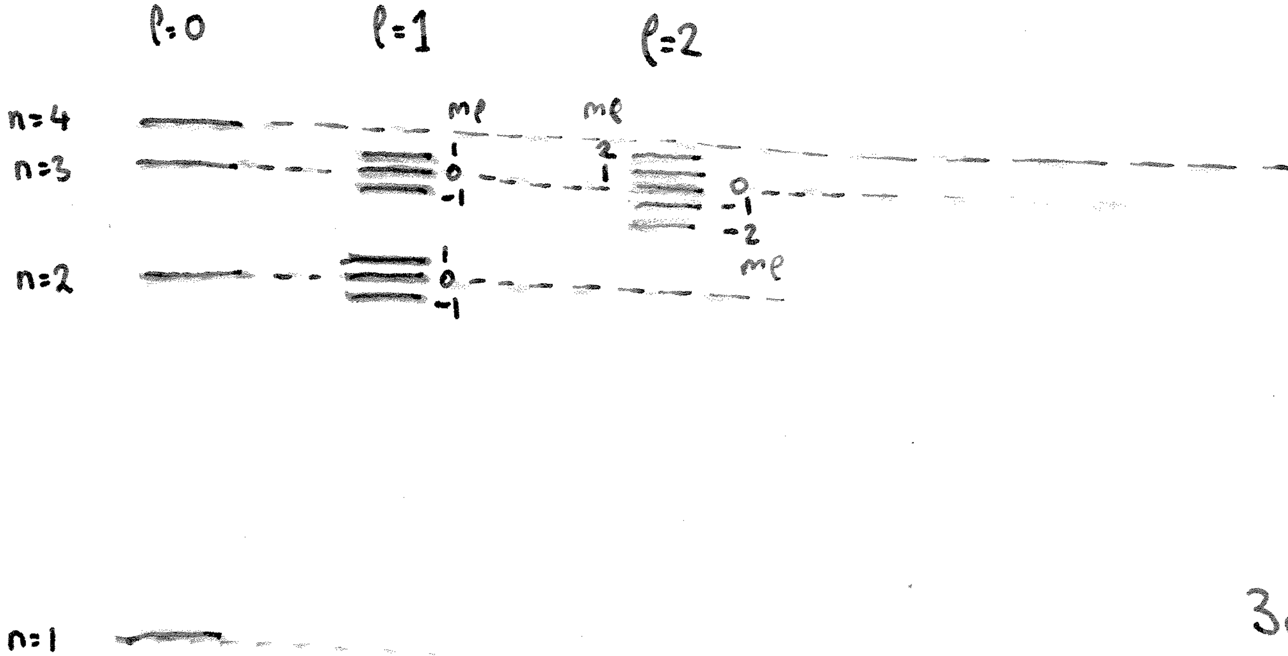


It is this shift that creates spectral lines.



$\Delta E = \mu_B B$

Electrons like to lower their energy $\Rightarrow$ μ parallel to B, angular momentum opposite to B



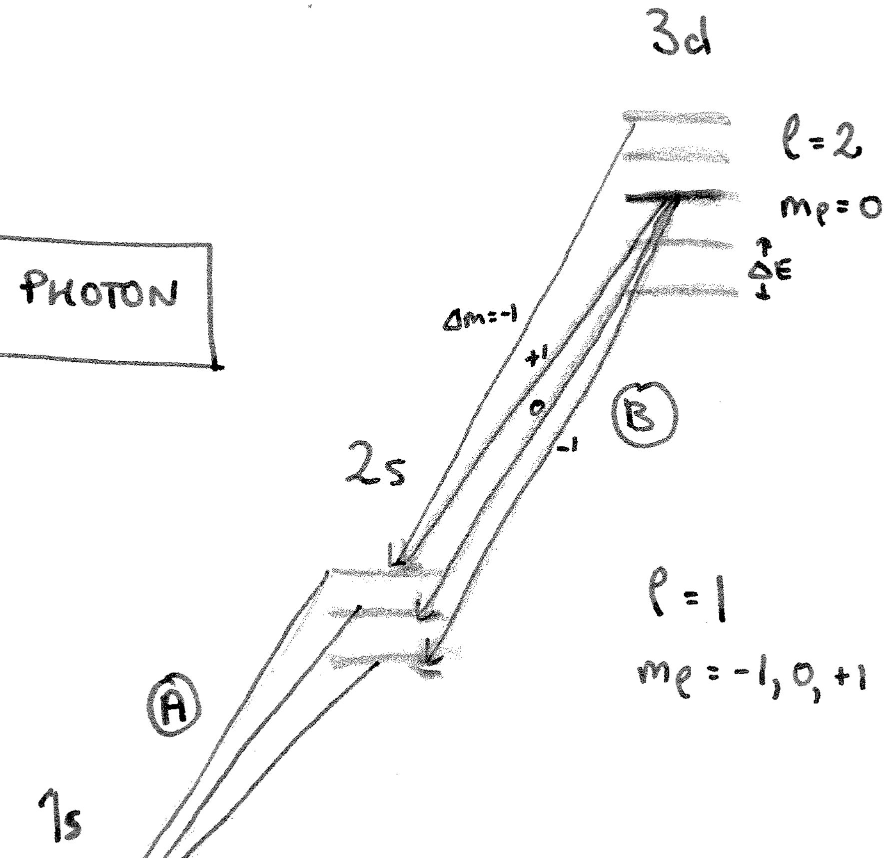
SELECTION RULES FOR PHOTON EMISSION

$$\Delta \ell = \pm 1$$

$$\Delta m_\ell = -1, 0, +1$$

3 LINES

(Photon has angular momentum $\ell = 1$)



$$\Delta E = \mu_B B$$

e.g. Calculate the frequency shift associated with the Zeeman effect in a 10T field

$$\Delta E = \mu_B B = h\Delta f$$

$$\Delta f = \frac{\mu_B B}{h} = \frac{(5.788 \times 10^{-5}\ \text{eV/T})}{4.14 \times 10^{-15}\ \text{eV s}} \times 10\text{T}$$

$$= 1.398 \times 10^{11}\ \text{Hz}$$

$$= \underline{0.14\ \text{GHz}}$$

What is the change in the photon energy associated with the two satellites?

$$\Delta E = \mu_B B = 5.788 \times 10^{-5}\ \text{eV/T} \times 10\text{T}$$

$$= 5.788 \times 10^{-4}\ \text{eV}$$

$$\simeq \underline{0.6\ \text{meV}}$$