Atomic and Molecular Physics

By

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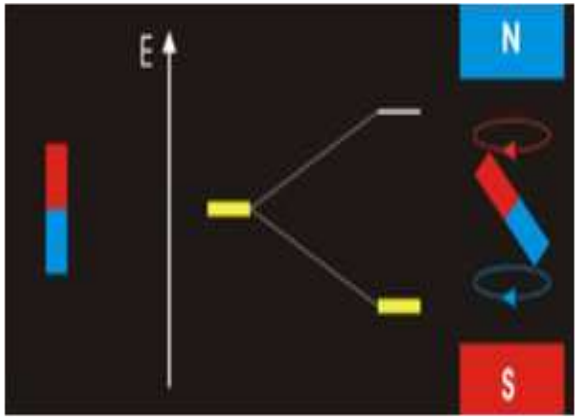
Zeeman effect



- Observed in atoms with no spin.
- Total spin of an *N*-electron atom is $\hat{S} = \sum_{i=1}^{N} \hat{s}_i$
- Filled shells have no net spin, so only consider valence electrons. Since electrons have spin 1/2, not possible to obtain $S = 0$ from atoms with odd number of valence electrons.
- Even number of electrons can produce $S = 0$ state (e.g., for two valence electrons, $S = 0$ or 1).
- All ground states of Group II (divalent atoms) have ns^2 configurations => always have $S = 0$ as two electrons align with their spins antiparallel.
- Magnetic moment of an atom with *no spin* will be due entirely to *orbital* motion: $\hat{\mu} = -\frac{\mu_B}{\hbar}\hat{L}$

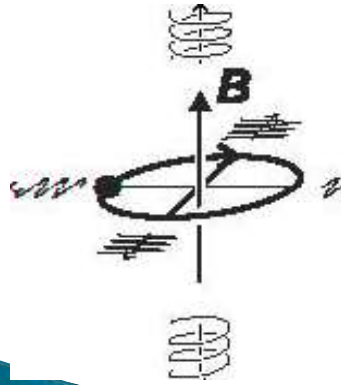
Normal Zeeman effect transitions

- *Longitudinal Zeeman effect:* Observing along magnetic field, photons must propagate in *z*-direction.
  - Light waves are transverse, and so only *x* and *y* polarizations are possible.
  - The *z*-component ($\Delta m_l = 0$) is therefore absent and only observe $\Delta m_l = \pm 1$.
  - Termed σ-components and are circularly polarized.
- *Transverse Zeeman effect:* When observed at right angles to the field, all three lines are present.
  - $\Delta m_l = 0$ are linearly polarized || to the field.
  - $\Delta m_l = \pm 1$ transitions are linearly polarized at right angles to field.

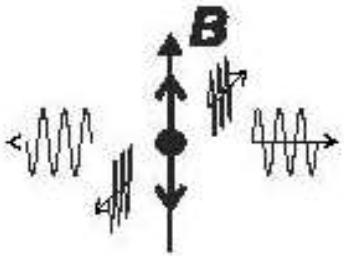
Zeeman effect transitions

- Last two columns of table below refer to the polarizations observed in the longitudinal and transverse directions.
- The direction of circular polarization in the longitudinal observations is defined relative to *B*.
- Interpretation proposed by Lorentz (1896)

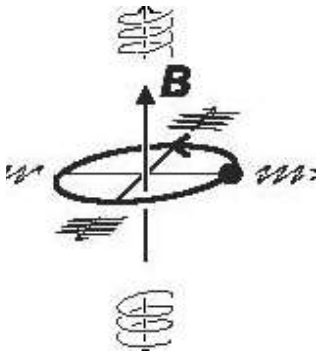
σ^- (Δm_l=-1)



π (Δm_l=0)

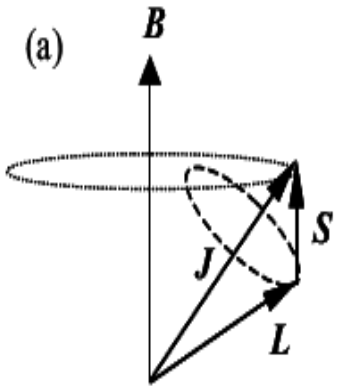


σ^+ (Δm_l=+1)



Δm_l	Energy	Polarization	
		Longitudinal observation	Transverse observation
+1	$h\nu_0 - \mu_B B$	σ^+	$\mathcal{E} \perp B$
0	$h\nu_0$	not observed	$\mathcal{E} \parallel B$
−1	$h\nu_0 + \mu_B B$	σ^-	$\mathcal{E} \perp B$

Anomalous Zeeman effect



- Discovered by Thomas Preston in Dublin in 1897.
- Occurs in atoms with non-zero spin => atoms with electrons.
- In *LS*-coupling, the spin-orbit interaction couples the spin and orbital angular momenta to give a total angular momentum according to

$$\hat{J} = \hat{L} + \hat{S}$$

- In an applied *B*-field, *J* precesses about *B* at the Larmor frequency.
- *L* and *S* precess more rapidly about *J* to due to spin-orbit interaction. Spin-orbit effect therefore stronger.