3.4 EXPLANATION OF FINE STRUCTURE OF SODIUM D LINES

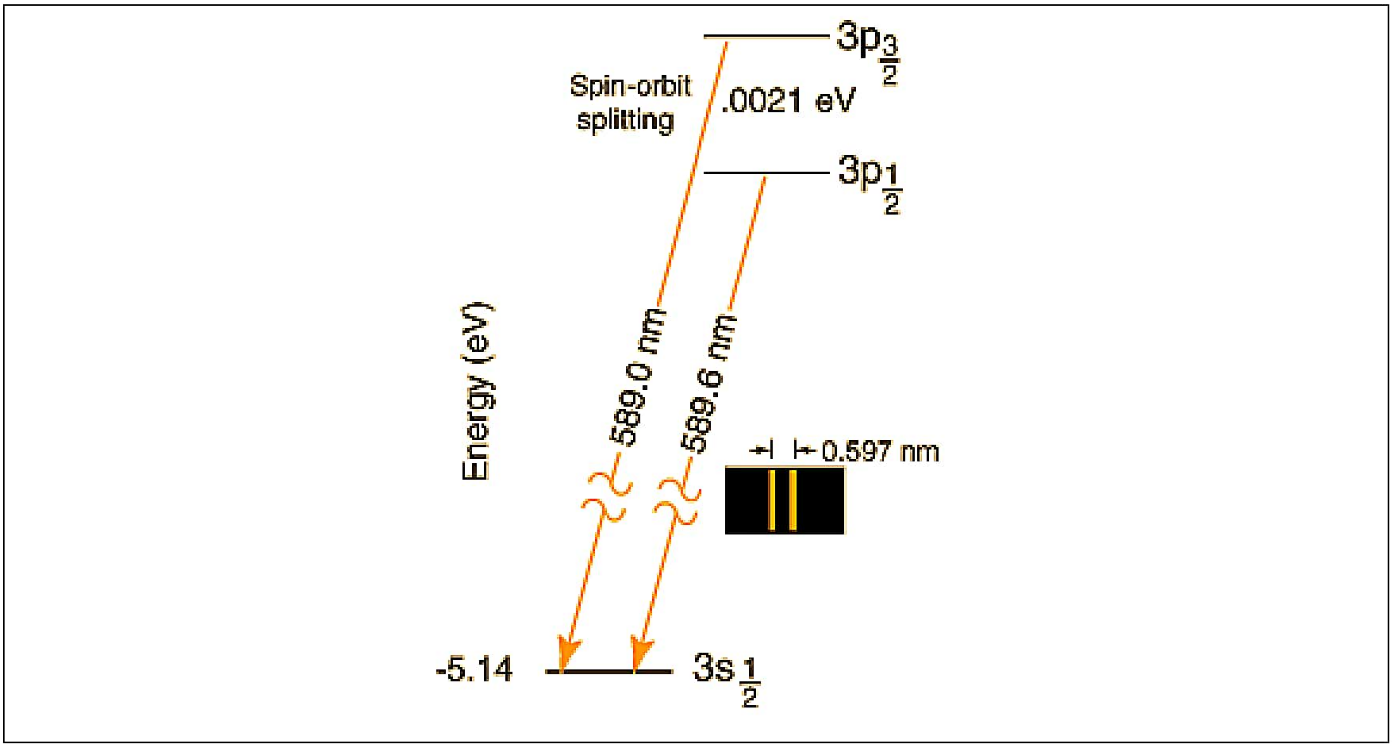

Figure 2: Fine structure of Sodium showing the D1 and D2 lines arising due to transitions from $3p_{3/2}$ to $3s_{1/2}$ and $3p_{1/2}$ to $3s_{1/2}$ respectively. The spin orbit coupling splits 3p level in two sublevels having an energy gap of 0.0021 eV.

Spectrum of Sodium atom arises due to the transition of the outer electron ($3s^1$) to excited states. And the available excited states are 3p, 3d, 4s, 4p and so on. The transitions between energy levels follow the selection rule $\Delta l = \pm 1$ and are shown in Figure3.1. The transition line 3p to 3s is called the Sodium D line and the energy change in this transition corresponds to the wavelength of yellow colour ($E_{3p} - E_{3s} = \frac{hc}{\lambda_{yellow}}$, this is the light you see in Sodium Lamps). When this line is observed with a high resolving power spectrometer it was found to have two components. These two components arise due to spin orbit splitting of the p level. The s state remains unsplitted with j =1/2. The p state splits in two levels corresponding to the j values 1/2 and 3/2 due to spin orbit interaction.

For s orbital	For p orbital
$l = 0, s = \frac{1}{2}$ $j = l \pm s$ $j = 0 \pm \frac{1}{2}$ $j = \frac{1}{2}$	$l = 1, s = \frac{1}{2}$ $j = l \pm s$ $j = 1 \pm \frac{1}{2}$ $j = \frac{1}{2}, \frac{3}{2}$

The energy change (in terms of wave number) due to spin orbit interaction is given by (derivation of this formula beyond the scope of this unit. This is given here just for the sake of information)

$$\Delta\varepsilon = -\frac{R_\infty \alpha^2 Z}{2n^3 l(l+\frac{1}{2})(l+1)}\left[j(j+1) - l(l+1) - s(s+1)\right]$$

where R_∞ is Rydberg constant and α is fine structure constant having value 1/137, Z is atomic number and n,l, j and s have their usual meaning. Thus in spite of having same n, l and s, the energy is different for different j value, which causes splitting of levels. And that's why the D line, is actually as shown in Figure 2. The two components are called D1 and D2 lines of Sodium with wavelengths 589.0 and 589.6 nm. This is also called as fine structure of Sodium line. The selection rule for transition is $\Delta j=0,\pm 1$.

Transitions other than the 3p to 3s are also doublet. Like 3p-3d transition of diffuse series. 3d level split in two components $3^2D_{5/2}$ and $3^2D_{3/2}$ and 3p splits in $3^2P_{3/2}$ and $3^2P_{1/2}$.So, now there are three transition lines rather than one as shown below in Figure 3.

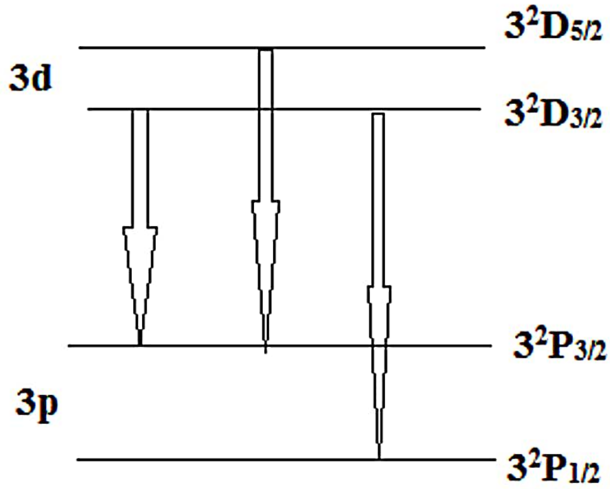

Figure3: Doublet of diffuse series (3d-3p) of Sodium atom

And same is the case for fundamental series also, i.e. spin orbit coupling adds more components in spectrum lines. Although the transition of Diffuse and fundamental has more than two lines, still they are called doublet, because doublet refers to the multiplicity of the energy level (i.e. the number of splitted energy levels) not the number of components of spectrum.

Apart from fine structure splitting there are more factors that cause further splitting of energy levels, like hyperfine splitting- due to nuclear spin angular momentum, Zeeman splitting- because of external magnetic field, Stark splitting-because of external electric field. These you will be studying later. Here, we will discuss the Zeeman effect or Zeeman splitting.