B.Sc-3rd Year (Comp.Sci) Physics:- Atomic & Molecular

Unit-4

Date 31/03/2020
Page 21

Atom in External Field

Splitting of D_1 and D_2 lines of Sodium

OR

Discuss the Zeeman Pattern of D_1 and D_2 lines of Sodium

Principal series doublet of sodium consist of two lines D_1 & D_2 having wavelength 5890Å and 5896Å respectively

Emission of D_1 line is due to transition

$$3^2P_{1/2} \longrightarrow 3^2S_{1/2}$$

Emission of D_2 line is due to transition

$$3^2P_{3/2} \longrightarrow 3^2S_{1/2}$$

when subject to a weak magnetic field, each line gets splitted further. splitting of energy level is given by

Electronic configuration of sodium, having Atomic Number 11 → $1S^2\ 2S^2\ 2p^6\ 3S^1$

* In spectral notation, the state of atom obey L-S coupling is denoted as

$$n^{2S+1}L_J$$ *

For sodium we have following values of n, l, s & j (Compare above notation)

Level	n	l	s	j
$3^2S_{1/2}$	3	0	1/2	1/2
$3^2P_{1/2}$	3	1	1/2	1/2
$3^2P_{3/2}$	3	1	1/2	3/2

** For D_1 line

When no magnetic field is applied, ν_0 is the frequency of D_1 line.

When weak magnetic field is applied the energy state $3^2S_{1/2}$ and $3^2P_{1/2}$ split up

Energy state $3^2S_{1/2}$ (lower) gets split up into $2j+1$ here $j = 1/2$ $(2 \times \frac{1}{2} + 1) = 2$

$(2J+1) = 2$ sub-levels by using Lande's g factor

$$g = 1 + \frac{J(J+1) + S(S+1) - l(l+1)}{2j(j+1)}$$

$$g = 1 + \frac{\left(\frac{1}{2}\right)\left(\frac{3}{2}\right) + \frac{1}{2}\left(\frac{3}{2}\right) - 0}{2\left(\frac{1}{2}\right)\left(\frac{3}{2}\right)}$$

$$\boxed{g = 2}$$

Since $j = 1/2$ so $m_j = +J$ to $-j$
$m_j = 1/2$ to $-1/2$

$\therefore$ $g m_j = 2 \times \frac{1}{2} = 1$

$2 \times -1/2 = -1$

$$\boxed{g m_j = +1 \text{ or } -1}$$

In the same way for $3^2 P_{1/2}$ get split up into $(2J+1)$ here $j = 1/2$

$(2J+1) = \left(2 \times \frac{1}{2} + 1\right) = 2$ sublevels by using Lande's factor

$$g = 1 + \frac{J(J+1) + S(S+1) - l(l+1)}{2[J(J+1)]}$$

$$g = \frac{1 + \left(\frac{1}{2}\right)\left(\frac{3}{2}\right) + \left(\frac{1}{2}\right)\left(\frac{3}{2}\right) - (1)(2)}{2 \times \frac{1}{2} \times \frac{3}{2}}$$

$$\boxed{g = \frac{2}{3}}$$

Here $j = 1/2 \rightarrow m_j = -j$ to $+j$

$-1/2$ to $+1/2$

when $m_j = +1/2$, $g = 3/2$

$$g m_j = \frac{2}{3} \times \frac{1}{2} = \frac{1}{3}$$

$$g m_j = \frac{2}{3} \times -\frac{1}{2} = -\frac{1}{3}$$

$$\boxed{g m_j = +1/3 \text{ to } -1/3}$$

Now in these two level transition occur due to this selection rule

$$\Delta m_j = 0, 1 \text{ or } -1$$

m_j (transition) $0 \rightarrow 0$ is not allowed except $m_j = 0 \rightarrow m_j = 0$

Now $\Delta m_j = 0$ (Two transition allowed)

Two transitions are allowed form

$^2P_{1/2} \rightarrow {}^2S_{1/2}$ (see in fig next page)

from $m_j = 1/2 \rightarrow m_j = 1/2$ $\boxed{\Delta m_j = \left(\frac{1}{2} - \frac{1}{2}\right) = 0}$

$m_j = -1/2 \rightarrow m_j = -1/2 \rightarrow \Delta m_j = 0$

for $\Delta m_j = 1$ (One transition allowed)

Transition is allowed from
$^2P_{1/2}$ to $^2S_{1/2}$

from $m_j = 1/2 \rightarrow m_j = -1/2$ $\quad \Delta m_j = \frac{1}{2} - (-\frac{1}{2}) = 1$

for $\Delta m_j = -1$ (One transition allowed)

$^2P_{1/2} \longrightarrow {}^2S_{1/2}$

for $m_j = -1/2 \longrightarrow m_j = 1/2$ $\quad \boxed{\Delta m_j = -\frac{1}{2} - \frac{1}{2} = -1}$

Purpose only understanding

Not write in paper
↓
Sodium ka [Emission spectra study kr rhai hai]

$^2P_{1/2}$
$^2S_{1/2}$

Now in previous topic Anomalous Zeeman effect we have to calculate (Eq^n 4)

$$\nu = \nu_0 + \Delta\nu [g_i (m_j)_i - g_f (m_j)_f] \rightarrow (1)$$

Total four transition allowed $\quad {}^2P_{1/2} - {}^2S_{1/2}$
initial $\quad$ final

$\nu_1 = \nu_0 + \Delta\nu [$

$(m_j)_i = 1/2 \qquad g_i = 2/3$

$(m_j)_f = 1/2 \qquad g_f = 2$

put in above eq^n (1)

$\nu = \nu_0 + \Delta\nu \left[\frac{2}{3} \times \frac{1}{2} - \frac{2 \times 1}{2} \right]$ first case

$\nu = \nu_0 + \Delta\nu \left(\frac{1}{3} - 1 \right)$

$\nu_1 = \nu_0 - \frac{2}{3} \Delta\nu \longrightarrow$ (A)

** $\nu_2 = \nu_0 + \Delta\nu \left[g_i (m_j)_i - g_f (m_j)_f \right]$ second case

$(m_j)_i = -1/2 \quad g_i = 2/3$

$(m_j)_f = -1/2 \quad g_f = 2$

$\nu_2 = \nu_0 + \Delta\nu \left[\frac{2}{3} \times \frac{-1}{2} - 2 \times \left(\frac{-1}{2} \right) \right]$

$\nu_2 = \nu_0 + \frac{2}{3} \Delta\nu \longrightarrow$ (B)

llly $\nu_3 = \nu_0 + \Delta\nu \left[\frac{1}{3} - (-1) \right] = \nu_0 + \frac{4}{3} \Delta\nu$

$\nu_4 = \nu_0 + \Delta\nu \left[\frac{-1}{3} - (1) \right] = \nu_0 - \frac{4}{3} \Delta\nu$

Thus here we find D_1 line splits into 4 lines See in fig NextPage

** for D_2 lines

When no magnetic field is applied ν_0 is the frequency of D_2 line when magnetic field is applied

The energy states $3^2P_{3/2}$ and $3^2S_{1/2}$ split up

$3^2S_{1/2}$ will split up into $(2J+1) = 2$ sublevels

$(j = 1/2)$ $j = 1/2$ $l = 0$

$s = 1/2$

$$g = 1 + \frac{j(j+1) + s(s+1) - l(l+1)}{2j(j+1)}$$

$$\boxed{g = 2}$$

$j = 1/2 \longrightarrow m_j = +j$ to $-j$

$+1/2$ to $-1/2$

$g m_j = \frac{1}{2} \times 2 = 1$

$g m_j = -\frac{1}{2} \times 2 = -1$

$(2s+1)$ 4
$(2l+1)$
$m_j = m_l + m_s$
$(2j+1)$

$g m_j = +1$ to -1

$3^2P_{3/2}$ will split into $(2J+1) = 4$ sublevels

$(j = 1/2)$

$j = 3/2$
$s = 1/2$
$l = 1$

$$g = 1 + \frac{j(j+1) + s(s+1) - l(l+1)}{2j(j+1)}$$

$$g = 4/3$$

$j = 3/2 \quad m_j = -j$ to $+j$

$g = 4/3 \quad m_j = 3/2, 1/2, -1/2, -3/2$

$$g m_j = \frac{4}{3} \times \frac{3}{2} = \frac{4}{2} = 2$$

$$\frac{4}{3} \times \frac{1}{2} = 2/3$$

$$\frac{4}{3} \times -\frac{1}{2} = -2/3$$

$$\frac{4}{3} \times -\frac{3}{2} = -2$$

$$g m_j = 2, 2/3, -2/3, -2$$

The allowed transition for those

$\Delta m_j = 0, 1$ or -1

$m_j = 0 \rightarrow m_j = 0$ (not allowed)

for $\Delta m_j = 0$

Two transition allowed $3^2P_{3/2} \rightarrow 3^2S_{1/2}$

$m_j = 1/2 \rightarrow m_j = 1/2 \qquad \Delta m_j = 0$

$m_j = -1/2 \rightarrow m_j = -1/2 \qquad \Delta m_j = 0$

for $\Delta m_j = 1$

Two transition allowed from $^2P_{3/2} \rightarrow {}^2S_{1/2}$

$m_j = 3/2 \rightarrow m_j = 1/2$ and from $m_j = 1/2 \rightarrow m_j = -1/2$

$\Delta m_j = 1 \qquad \Delta m_j = 1$

Date / /
Page 29

$\Delta m_j = -1$

Two transition allowed from $^2P_{3/2}$ to $^2S_{1/2}$

$m_j = -1/2 \rightarrow m_j = -1/2 \qquad \Delta m_j = -1$

$m_j = -3/2 \rightarrow m_j = -1/2 \qquad \Delta m_j = -1$

The emitted frequencies are ($3^2P_{3/2} \rightarrow 3^2S_{1/2}$)

$\nu_1 = \nu_0 + \Delta\nu \left[g_i (m_j)_i - g_f (m_j)_f \right]$

$\nu_1 = \nu_0 + \Delta\nu \left[\frac{4}{3} \times \frac{1}{2} - 2 \times \frac{1}{2} \right]$

$g_i = 4/3 \quad (m_j)_i = 1/2$
$g_f = 2 \quad (m_j)_f = 1/2$ } put in above

$\nu_1 = \nu_0 + \Delta\nu \left[\frac{2}{3} - 1 \right] = \nu_0 - \frac{1}{3}\Delta\nu$

IIIy $\nu_2 = \nu_0 + \Delta\nu \left[-\frac{2}{3} - (-1) \right] = \nu_0 + \frac{1}{3}\Delta\nu$

$\nu_3 = \nu_0 + \Delta\nu \left[2 - (-1) \right] = \nu_0 + \Delta\nu$

$\nu_4 = \nu_0 + \Delta\nu \left[\frac{2}{3} - (-1) \right] = \nu_0 + \frac{5}{3}\Delta\nu$

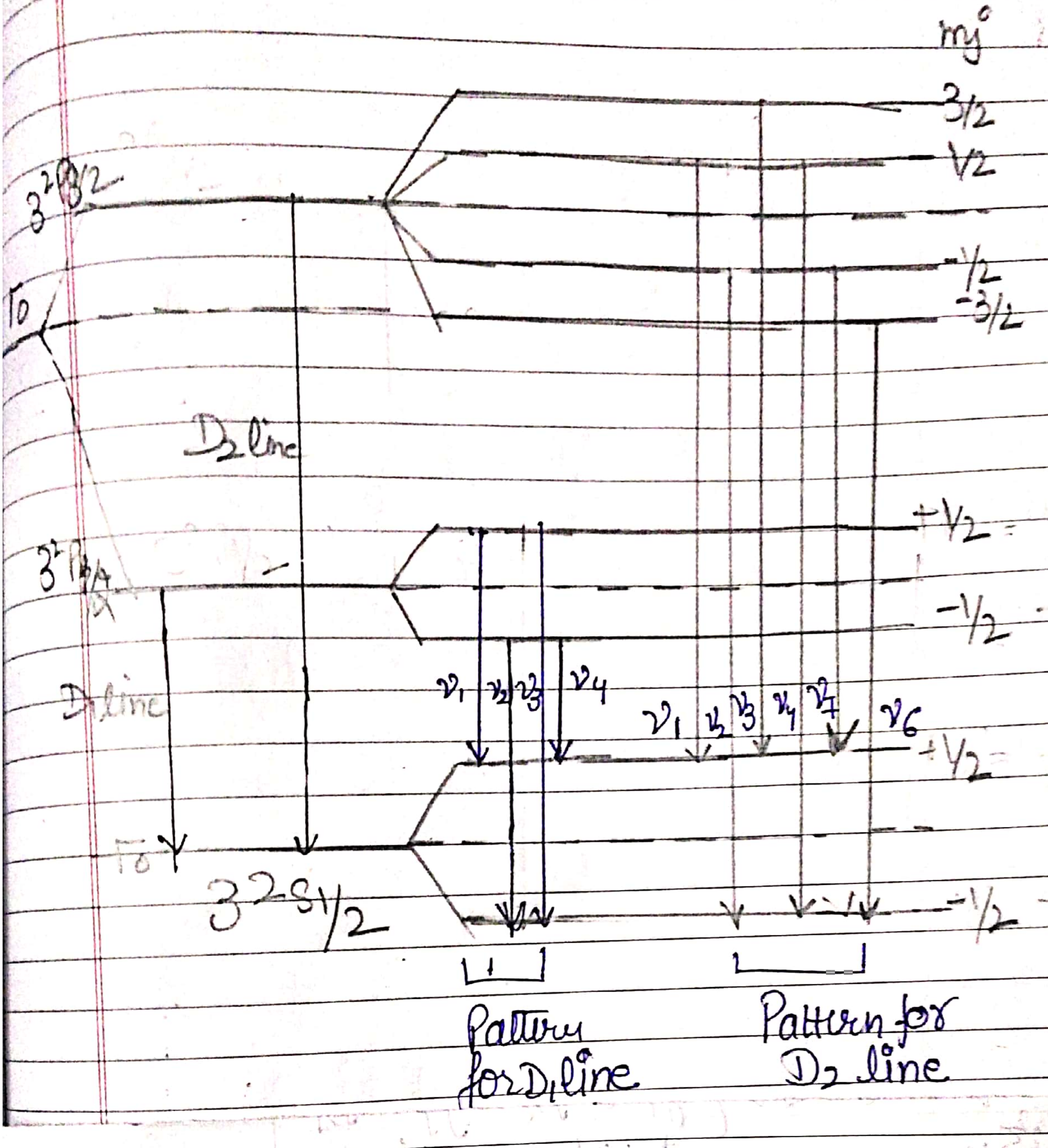
$\nu_5 = \nu_0 + \Delta\nu \left[\frac{-2}{3} - (+1) \right] = \nu_0 - \frac{5}{3}\Delta\nu$

$\nu_6 = \nu_0 + \Delta\nu \left[-2 - (-1) \right] = \nu_0 - \Delta\nu$

Date ___/___/___
Page ______

ClassSmart

Zeeman Pattern of principal series Doublet



$\Delta m_j = \begin{cases} 0 = \pi \text{ Component} \\ \pm 1 \ \ \sigma \text{ Component} \end{cases}$ except $0 \to 0$

$^2P_{1/2} \to {}^2S_{1/2}$ have 2σ, 2π Component

$^2P_{3/2} \to {}^2S_{1/2}$ have 2σ, 4π Component

Scanned by CamScanner