Research Journal of Physical Sciences E-ISSN 2320–4796
Vol. **4(7),** 1-4, September **(2016)** *Res. J. Physical Sci.*

Spectroscopic Behavior and Sextet Formation of some Neon lines in Weak Magnetic Field

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Available online at: www.isca.in, www.isca.me
Received 29th May 2016, revised 11th August 2016, accepted 30th August 2016

Abstract

The Zeeman patterns of some neon lines forming sextet in weak magnetic field (B<1T) have been studied. It has been shown that, every neon line of sextet is split into two π-components and four σ- components. It is found that the intensity distribution and width of the separation of π- components of 638.2nm line are different from 659.9 and 603.0 nm lines. The observed g-factors for both states are compared with Lande'g-factors. All the possible electronic transitions for $^3P_1$-$^1P_1$ state of 659.9 nm line are shown. It is observed that the transition between m_J =0 and m_J=0 for upper and lower states of $^3P_1$-$^1P_1$ is forbidden.

Keywords: Sextet, High resolution, Energy shift, Multiplet, Zeeman splitting, Spin-Orbit coupling, Spectral terms.

Introduction

The complexity of the spectral lines of an atom is based on the concept of electron-spin. In presence of an external magnetic field, the quantum states of the atom are changed and splitting of the energy levels occurs. The splitting arises because of the interaction of the magnetic moment of the atom with the external magnetic field; slightly shift the energy of the atomic levels. The energy shift depends upon the relative orientation of the magnetic moment and the magnetic field.

If the spectrometer with high resolution is used and the external magnetic field is weak then the spectral lines are split into more than three components. The reason is that, in addition to orbital angular momentum, electrons possess spin angular momentum and associated magnetic moment. The orbital and spin angular moment have different Zeeman splitting because electron spin has twice the magnetic moment than due to orbital motion with the same angular momentum.

In the weak magnetic field (B<1T), the neon light is dispersed in a spectrograph and is observed with a telescope. It is found that, each neon line is split into several unresolved components due to the transitions of the spectral lines among various sub energy levels within each multiplet. The Zeeman splitting are observed clearly with the help of polarizer and Fabry-Perot interferometer. The energies of the perturbed states in the magnetic field are symmetrically distributed around the unperturbed level. The splitting of those perturbed levels, however, vary from one level to another since the spectral line arises due to transition between two energy levels, each of which splits in the presence of magnetic field, the resulting pattern is calculated by considering the splitting of each energy level[1-6].

Methodology

Neon lamp was placed at the focus of the lens of a collimator of a spectrometer. The source was so placed that it passes through a Fabry-Perot at a single angle. The entrance slit is adjusted at the focus of the focusing lens to get the image of the source. If this adjustment is not done systematically, the telescope when focused on the slit image will not show clear interference patterns. Source was viewed through the FP to align the optical flats on the FP. Rings were superimposed on the source. The magnetic field was settled using the current regulator. Indicator was adjusted in the suitable range from 3-7 m amp. The power supply variac was turned up and down together with the current regulator to keep the regulator in its working range. The strength of magnetic field was measured with the help of Hall probe. The face of the probe was oriented parallel to the pole faces. Hall voltage was measured twice at the same Hall current with the probe; turned 180^0 between measurements at single frequency source produced a single set of rings when the FP was interposed. The rings move in or out as the frequency increases or decreases. In weak magnetic field (B<1T), a state of a given J splits into 2J+1 Zeeman levels. The visible spectrum of neon was seen through the telescope. The telescope was replaced by CCD camera and clear spectrum of neon lines was observed[7-10].

Results and Discussion

The spectrum of neon lines observed in the present investigation was twenty eight. These lines were found of red-brown, red, orange, yellow and green colours respectively. The intensities of some neon lines of wavelengths 612.8nm, 630.4 nm, 653.3nm and 702.4 nm were found weak and so Zeeman splitting were not observed clearly. The intensities of some green neon lines of wavelengths 533nm and 534nm were also found weak. The actual observed neon lines were found twenty one. In the weak magnetic field (B<1T), these neon lines were split into number of components. Ten lines were split into three components (normal splitting), five lines into nine components (nonets), three lines into six components (sextets), two lines into twelve components and one into fifteen components respectively. In this paper, we have emphasized on those neon lines which form sextets[11-13].

In Table-1 these neon lines of sextet, the Zeeman patterns are symmetrical both in splitting as well as in the relative intensity of the components for 659.9 nm and 603.0 nm lines. However, the intensity distribution and the separation of the components of 638.2 nm line are different from 659.9nm and 603.0nm lines. The Zeeman patterns corresponding to π-components are enclosed within brackets and the patterns corresponding to σ-components are shown without bracket. It is found from the observations that, in all the neon lines of sextet, there are two π -components and four σ –components[14-16].

In Table-2 all the three neon line of sextet, the observed g-factors for lower and upper states are slightly different from Lande'g-factors. For 638.2 nm and 603.0 nm neon lines, there is a triplet- triplet transition between upper and lower states, however in case of 659.9nm neon line; there is a triplet-singlet transition between upper and lower states. It is remarkable that, all these three neon lines are resolved into six components in a weak magnetic field (B<1T) in this case.

Table-1
The Zeeman splitting, its patterns and spectral terms of the corresponding wavelengths

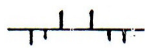
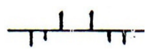
Wavelengths (nm)	Zeeman splitting	Zeeman patterns	Spectral terms (lower state)	Spectral terms (upper state)
659.9		$\pm\frac{(1)3\ 5}{2}$	$2P^53s$ $^1P_1$	$2p^53p$ $^3p_1$
638.2		$\pm\frac{10(12)22}{15}$	$^3P_1$	$^3D_1$
603.0		$\pm\frac{(2)20\ 22}{15}$	$^3P_1$	$^3P_1$

Table-2
The spectral terms and associated g –factors of the neon lines of the sextet

Wavelengths (nm)	Spectral terms (upper state)	Lande'g-factor (g_L)	Observed g-factor (g_o)	Spectral terms (lower state)	Lande'g-factor (g_L)	Observed g-factor (g_o)
659.9	$2P^53P$ $^3P_1$	1.500	1.501	$2P^53s$ $^1P_1$	1.000	1.005
638.2	$^3D_1$	0.500	0.503	$^3P_1$	1.500	1.501
603.3	$^3P_1$	1.500	1.501	$^3P_1$	1.500	1.501

Table-3
The spectroscopic terms and energy shifts of neon lines of sextet

Wavelengths (nm)	Unperturbed Level	No. of Zeeman Levels(2J+1)	g_L	m_J	m_Jg_L	ΔE (ev)
659.9	$^3P_1$	3	$\frac{3}{2}$	1,0,-1	$\frac{3}{2}, 0, -\frac{3}{2}$	$0.87X10^{-5}$,0, $-0.87X10^{-5}$
	$^1P_1$	3	1	1,0,-1	1,0,-1	$0.58X10^{-5}$,0, $-0.58X10^{-5}$
638.2	$^3D_1$	3	$\frac{1}{2}$	1,0,-1	$\frac{1}{2}, 0, -\frac{1}{2}$	$0.29X10^{-5}$,0, $-0.29X10^{-5}$
	$^3P_1$	3	$\frac{3}{2}$	1,0,-1	$\frac{3}{2}, 0, -\frac{3}{2}$	$0.87X10^{-5}$,0, $-0.87X10^{-5}$
603.0	$^3P_1$	3	$\frac{3}{2}$	1,0,-1	$\frac{3}{2}, 0, -\frac{3}{2}$	$0.87X10^{-5}$,0, $-0.87X10^{-5}$
	$^3P_1$	3	$\frac{3}{2}$	1,0,-1	$\frac{3}{2}, 0, -\frac{3}{2}$	$0.87X10^{-5}$,0, $-0.87X10^{-5}$

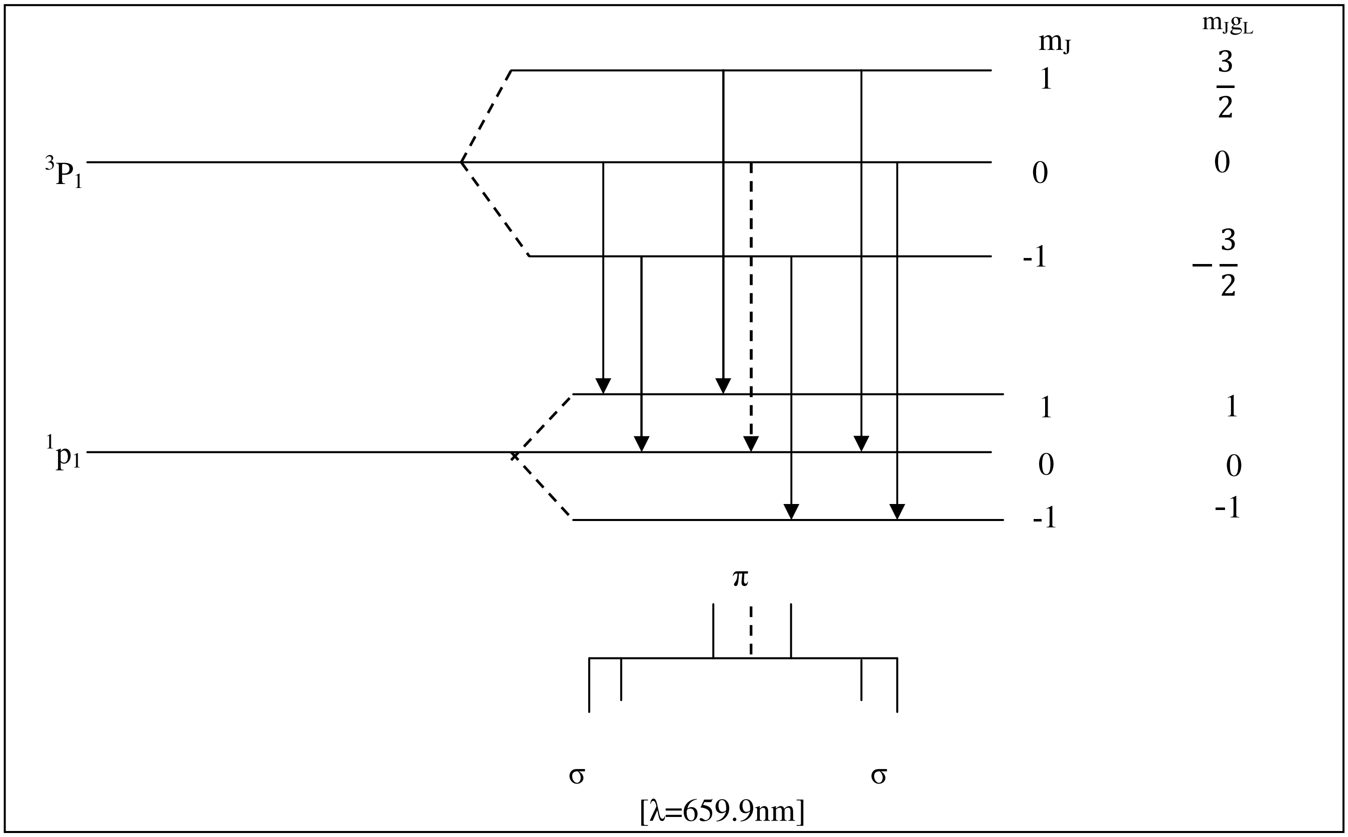


Figure-1
The energy level diagram for $^3P_1$ - $^1P_1$ transition at 659.9 nm line is shown

The Figure-1 indicates that the neon line of wavelength 659.9 nm is split into six components (sextet) in a weak magnetic field (B<1T). The Zeeman transition $m_j=0 \rightarrow m_j=0$ is forbidden. Same sextets are also formed for 638.2 and 603.0nm neon lines. The spacing between the spectral lines depend upon g-factors and hence on other properties such as spin-orbit coupling conditions and on quantum numbers. The π-components form a central group and σ-components form two symmetrically displaced groups. The π-components are polarized with electric vector parallel to the magnetic field, the σ-components with electric vector perpendicular to the magnetic field[17-19].

Conclusion

The Zeeman patterns are found symmetrical both in splitting and relative intensity of the components for 659.9 and 603.0nm neon lines but not for 638.2nm line. The observed g-factors for lower and upper states are slightly different from the Lande'g-factors for the same neon line.

The energy shifts of some neon lines of sextet are calculated at B=0.1T. The shift in energy shows the separation between two energy levels. The splitting of the spectral terms and the possible electronic transitions between $^3P_1$ and $^1P_1$ form sextet at 659.9 nm. The electronic transition between $m_J=0$ and $m_J=0$ is forbidden.

Acknowledgement

This study is done under Miner Research Project, sanctioned by UGC (University Grants Commission), New Delhi, Grant No:PSJ-4/13-14(ERO).

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