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STUDY OF ATOMIC EMISSION SPECTROSCOPY

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Abstract:

Part I: Known spectrum

To record atomic emission spectrum of a known light source and identify the transitions.

Part II: Unknown spectrum

To record atomic emission spectrum of an unknown light source and identify the elements and the trasitions.

Electronic transition

When an atom in its ground state is excited by an input of energy, its electron is 'promoted' from the lowest energy level to one of higher energy. The atom does not remain excited for ever. But the electron 'falls' from the higher energy level to one of lower energy and the atom re-emits energy as electromagnetic radiation. Thus an electronic transition from higher energy level E_2 to lower energy level E_1 results in the release of a photon from the atom of energy E equal to the difference in energy of the electronic energy levels involved in the transition. Frequency v, the wavelength 2 and the wave number of the light emitted are given by:

$$E_2 - E_1 = E = hv = hc/\lambda = hc\bar{v} \quad (3.1)$$

In spectroscopy energy levels are expressed in terms of wave number n cm'. In terms of wave numbers, Equation 3.1 becomes,

$$\overline{v_1} - \overline{v_2} = \bar{v} \quad (3.2)$$

$$\lambda(cm) = \frac{1}{\overline{v_1}(cm^{-1}) - \overline{v_2}(cm^{-1})}, \qquad \lambda(cm) = \frac{1}{\overline{v_1}(cm^{-1}) - \overline{v_2}(cm^{-1})} x10^7 \quad (3.3)$$

Graphically, the energy levels and electronic transitions are shown on an 'energy level diagram' for the atom as shown in Figures 3.2, 3.3 and 3.4 for sodium, mercury and He-Ne laser respectively.

Atomic spectrum

Electronic transition between a pair of levels gives rise to single sharp line in the atomic spectrum. When there are more than one exited states, and the electronic transitions take place to a common or to different lower levels the atomic spectrum consists of series of sharp lines. As the atomic energy levels are unique to an element the atomic spectrum too is unique and may be considered as the finger print of the element. The outer valence electrons of an atom determine the chemical and Optical properties of their atoms. They are usually involved in electronic transitions and the electrons in the closed inner orbits do not take part in the emission of spectral lines.

Spectral Terms

The electronic energy state is referred to as a 'term' and the corresponding energy as 'term value'. The standard data for energy levels of sodium, mercury and neon down loaded from National Institute of Science and Technology, USA (NIST) website http://physics.nist.gov are given in Table In the energy level diagram (Figures 3.2, 3.3 and 3.4) the term and term value of each level are shown. In the context of atomic spectra, atoms are divided into to two main categories, one electron system and many-electron system.

1) The alkali metals such as lithium sodium and potassium have a single valence electron outside completely filled sub shells. The valence electron in the alkali metals behaves like the orbiting electron in the hydrogen atom.

2) In many electron system the atoms have more then one valence or optical electrons outside completely filled sub shells.

In hydrogen like atoms the configuration of the single valence electron is considered for determining the term and the term value; in others more than one valence electrons are considered.

Quantum Numbers

Quantum numbers are used to describe the location or configuration of an electron in an atom and hence its energy state. The first quantum number is the principle quantum number, which is symbolized by n. This indicates the main energy level occupied by the electron. This number can only be positive integers: 1, 2, 3,... etc. Electron with lower n is generally closer to the nucleus. The second quantum number is the angular momentum quantum number, or the Azimuthal quantum number, which refers to the shape of the orbital that the electron is in, also referred to as the 'sublevel'. It is symbolized by *'l'*. The values of l are positive integers from 0 to $n-1$: $0, 1, 2, 3,... n-1$. When $l = 0$, the orbital is spherical and is designated as s-orbital; ; when l = 1, the orbital is barbell shaped and is designated as p-orbital. *Similarly* $l = 2, 3, 4, 5...$ orbital is designated *as d-, f-, g-, h-*...orbital respectively. The third quantum number is the Magnetic Quantum Number, symbolized by ml, which indicates the orientation of an orbital around the nucleus. The values of this quantum number are the integers that range from $- l$ to l. An electron is Fermion with spin $s=1/2\ \hbar$ .The last quantum number is the Spin Quantum Number, symbolized by *ms*, which indicates the direction of electron's spin. The values for this quantum number can be + 1⁄2 or - 1⁄2. There may be maximum of two electrons per orbital: one with spin up and $ms = +1/2$ and other with spin down and $ms = -1/2$.

Spectral notation

A spectroscopic term is symbolically represented as: $^{2s+1} L_J$, where

S is the total spin quantum number

L is the total orbital quantum number in spectroscopic notation.

2S+1 is the spin multiplicity: the maximum number of different possible states of *J* for a given *(L, S)* combination (takes values from *L-S* to *L+S*, differeng by unity) *J* is the total angular momentum quantum number.

The state of an atom with *L = 0, 1, 2, 3, 4, 5.....* is represented by the capital letter *S, P, D, F, G, H,......* etc., respectively. The value of the total angular momentum of the atom, J, is written as a subscript at the right of the letter representing *L*. The spin multiplicity is written as a superscript at the left of *L*.

The spectral line resulting from transitions from higher energy term T_2 to lower energy term T_1 is represented by T_1-T_2 [Notice: T_1 is written first]. For example, from Figure 3.2 we see that the principle series doublet line of sodium is to be designated as 3^2S-3^2P.

The Selection rule

While spectral lines result from electronic transitions between two levels, not every pair of levels can be considered for emission of spectral line. Thus in energy level diagrams (Figures 3.2, 3.3 and 3.4) not every pair shows a transition. Under ordinary conditions the spectrum lines are possible corresponding to the transition of an electron in selected pairs of levels. The selection of pairs of energy levels for emission (or absorption) of photon is governed by a selection rules derived quantum mechanics and are mentioned below:

1. l must change by +1 or -1, i.e., $\Delta l = \pm 1$
2. n is not restricted in any way and may change by any integral value, including zero.

Application

Since the energy levels and the spectral lines are unique to the element the emission spectrum of material has tremendous applications. In this experiment we consider following two applications.

1. Emission spectrum of known light source: Measure the wavelengths of spectral lines to identify the energy levels and the transitions.
2. Emission spectrum of unknown light source: Measure the wavelengths of spectral lines to identify the elements present and also the energy levels and the transition.

Experimental

Spectrum of known element

The spectrometer is set up as shown in Figure 3.1 for recording emission spectrum. A sodium lamp normally used in spectroscopy laboratory is switched on and allowed to warm up for 15 min. OOIBase32 is launched. The calibration coefficients provided by the manufacturer are used and the spectrometer is configured. Dark spectrum is 'stored' and 'subtracted' and the spectrometer is held ready in scope mode. The tip of the fibre is pointed toward the sodium lamp and the 'snapshot' of the spectrum is taken. The 'processed' spectrum is 'saved" and is shown in Figure 3.5. The procedure is repeated with a mercury vapour lamp and then with a He-Ne laser (both normally used in student laboratory); the collected spectra are shown Figures 3.6 and 3.7 respectively. By positioning the cursor at the peak intensity of the lines successively the corresponding wavelength, pixel number and intensity are noted as shown in Table 3.7.

By comparing the experimental spectrum of sodium lamp (Figures 3.5) and the corresponding spectrometer readings of Table 3.7 with the data for the standard spectrum of sodium given in Table 3.1 and the energy level diagram in Figure 3.2, the lines in the experimental spectrum are identified and the corresponding standard wavelengths are entered in Table 3.7. Similarly by comparing the experimental spectrum of Mercury lamp (Figures 3.6) and the corresponding spectrometer readings of Table 3.7 with the data for the standard spectrum of mercury given in Table 3.2 and the energy level diagram in Figure 3.3, the lines in the experimental spectrum are identified and the corresponding standard wavelengths are entered in Table 3.7. Next, by comparing the experimental spectrum of He-Ne laser (Figures 3.7) and the corresponding spectrometer readings of Table 3.7 with the data for the standard spectrum of He-Ne laser given in Table 3.3 and the energy level diagram in Figure 3.4, the line in the experimental spectrum is identified and the corresponding standard wavelength are entered in Table 3.7.

For the identified lines in all the three spectra, the terms and term values of the levels involved in the transition are also given in Table 3.7. Using these term values in equation 3.2 the expected wave length of the line is calculated and is given in Table 3.7.

Spectrum of unknown element

We used two commercial fluorescent lamps as light sources of unknown elements:

1. Tube light, generally used for home lighting.
2. Cold Fluorescent Lamp (CFL) used for home lighting (Oreva make).

We repeated the procedure described in section 3.31 above and recorded the emission spectra that are shown in Figures 3.8 and 3.9 respectively. For the convenience of comparing the experimental spectra of tube light and CFL with that of mercury, the spectrum of mercury from Figure 3.6 is shown at the bottom of Figures 3.8 and 3.9.

The spectrum of Tube light and CFL are similar to that of mercury. By comparing the lines in the two spectra and the corresponding spectrometer readings of Table 3.7 with the standard data for mercury given in Table 3.2 and also using the energy level diagram in Figure 3.3 the lines in the experimental spectra are identified. The standard wavelengths corresponding to the lines in experimental spectra are entered in Table 3.7. The terms and term values of the levels involved in the transition are also given for the identified lines in Table 3.7. Using these term values in equation 3.2 the expected wave length of the line is calculated and is given in Table 3.7.

Data

Standard data

1. Tables 3.1, 3.2 and 3.3 give NIST data on energy levels of neutral atoms of sodium, mercury and neon respectively.
2. Table2 3.4, 3.5 and 3.6 give NIST data on persistent lines of neutral sodium, mercury and neon respectively.

Experimental data

1. Table 3.7 gives spectrometer data for lines in known light sources and the data for matching lines in the standard spectrum for the known element.
2. Table 3.8 gives spectrometer data for lines in unknown light sources and the data for matching lines in the standard spectrum for the known element.

Calculations, Results

Spectrum of known light source

The experimental spectrum of sodium lamp (Figure 3.5) has one line which is identified as the spectral lines of neutral sodium. There are no lines which are not identified. A close examination of this line shows two shoulders. Since the separation between the sodium doublets is 0.6 nm and the resolution of the spectrometer is 1.09 the two could not be resolved and the shoulders are taken as the positions of the components to measure their wavelengths. The measured wavelengths (Table 3.7) of the spectral lines in experimental spectra agree with the standard wavelengths (Table 3.4) of the neutral sodium within ±0.8 nm.

The experimental spectrum of mercury lamp (Figure 3.6) has six lines which are identified as the spectral lines of neutral mercury. There are no lines which are not identified. The measured wavelengths (Table 3.7) of the spectral lines in experimental spectra agree with the standard wavelengths (Table 3.5) of the neutral mercury within 10.2 nm. Fifth and sixth lines are so close that they look like doublets with measured separation of 1.7 nm while the standard value of separation is 2.1 nm. Since the resolution of the spectrometer is 1.09 the two could be resolved.

The experimental spectrum of He-Ne laser (Figure 3.7) has one line which is identified as the spectral lines of neutral neon. There are no lines which are not identified. A close examination of this line shows two shoulders. The measured wavelength (Table 3.7) of the spectral line is 633.42 while the nearest lines in standard spectrum for neutral neon (Table 3.6) have wavelengths of 626.65nm and 638.30 nm [Table 3.4]. Measured value is midway between the two and has FWHM of 2.3 nm.

Spectrum of unknown light source

The experimental spectrum of tube light (Figure 3.8) has six sharp lines super imposed on a broad continuous spectrum. All the six spectral lines are identified as the spectral lines of neutral mercury. There are no lines which are not identified. The measured wavelengths (Table 3.8) of all the spectral lines in experimental spectra agree with the standard wavelengths (Table 3.5) of respective lines of neutral mercury within ±0.4 nm. The broad continuum may be due to the heating elements used in the tube.

The experimental spectrum of CFL (figure 3.9) has six sharp intense lines and three sharp low intensity lines super imposed on a flat low intensity continuous spectrum. Six spectral lines are identified as the spectral lines of neutral mercury; the other three may be due to ionized mercury. The measured wavelengths of all the identified spectral lines in experimental spectra agree with the standard wavelengths of respective lines of neutral mercury within ±0.2 nm [Table 3.5]. As this is a 'cold' fluorescent lamp the broad continuum is of lower intensity as compared to the tube light.

TABLE 3.1 Energy Levels of neutral sodium (NaI)

SN	Configuration	Term	J	Energy (cm^{-1})
1	3s	^2S	½	0.000
2	3p	$^2P^0$	½	16956.172
3			3/2	16973.368
4	4s	^2S	½	25739.991
5	3d	^2D	5/2	29172.839
6			3/2	29172.889
7	4p	$^2P^0$	½	30266.99
8			3/2	30272.58
9	4f	$^2F^0$	5/2,7/2	34586.92
10	5p	$^2P^0$	½	35040.38
			3/2	3504.85
	Na II $2s^2$ $2p^6$ ($^1S_0$)	Limit		41449.451

Table 3.2 Energy Levels of neutral mercury (Hg I)

SN	Configuration	Term	J	Energy (cm^{-1})
1	$5d^{10}(^1S)6s^2$	^1S	0	0.000
2	$5d^{10}(^1S)6s$ 6p	$^3P^0$	0	37645.080
3			1	39412.300
4			2	44042.977
5	$5d^{10}(^1S)6s6p$	$^1P^0$	1	54068.781
6	$5d^{10}(^1S)6s7s$	^3S	1	62350.456
7	$5d^{10}(^1S)6s7s$	^1S	0	63928.243
8	$5d^9 6s^2 6p$	$^3P^0$	2	68886.60
9	$5d^{10}(^1S)6s7p$	$^3P^0$	0	69516.66
10			1	69661.89
11			2	71207.51
12	$5d^{10}(^1S)6s7p$	$^1P^0$	1	71295.15
13	$5d^{10}(^1S)6s6d$	(1/2,3/2)	2	71333.182
14		(1/2,5/2)	1	71336.164
15	$5d^{10}(^1S)6s6d$		2	71396.220
16			3	71431.311
	Hg II (2S1/2)	Limit		84184.1

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Table 3.3 Energy Levels of neutral neon (Ne I)

SN	Configuration	Term	J	Energy (cm^{-1})
1	2p6	1S	0	0.00
2	$2p^5(^2P^o_{3/2})3s$	$^2[3/2]^0$	2	134041.8400
3			1	134459.2871
4	$2p^5(^2P^o_{1/2})3s$	$^2[1/2]^0$	0	134818.6405
5			1	135888.7173
6	$2p^5(^2P^o_{3/2})3p$	$^2[1/2]$	1	148257.7898
7			0	150917.4307
8	$2p^5(^2Po_{3/2})3s$	$^2[5/2]$	3	149657.0393
9			2	149824.2215
10	$2p^5(^2P^o_{3/2})3s$	$^2[3/2]$	1	150121.5922
11			2	150315.8612
12	$2p^5(^2P^o_{1/2})3s$	$^2[3/2]$	1	150772.1118
13			2	150858.5079
14	$2p^5(^2P^o_{1/2})3s$	$^2[1/2]$	1	151038.4524
15			0	152970.7328
16	$2p^5(^2P^o_{3/2})4s$	$^2[3/2]^0$	2	158601.1152
17			1	158795.9924
18	$2p^5(^2P^o_{1/2})4s$	$^2[1/2]^0$	0	159379.9935
19			1	159534.6196
20	$2p^5(^2P^o_{3/2})3d$	$^2[1/2]^0$	0	161509.6305
21			1	161524.1739
22	$2p^5(^2P^o_{3/2})3d$	$^2[7/2]^0$	4	161590.3412
23			3	161592.1200
24	$2p^5(^2P^o_{3/2})3d$	$^2[3/2]^0$	2	161607.2609
25			1	161636.6175
26	$2p^5(^2P^o_{3/2})3d$	$^2[5/2]^0$	2	161699.6613
27			3	161701.4486
28	$2p^5(^2P^o_{1/2})3d$	$^2[5/2]^0$	2	162408.6536
29			3	162410.1736
30	$2p^5(^2P^o_{1/2})3d$	$^2[3/2]^0$	2	162419.9818
31			1	162435.6780
32	$2p^5(^2P^o_{1/2})4p$	$^2[1/2]^0$	0	164285.8872
33	$2p^5(^2P^o_{3/2})4d$	$^2[7/2]^0$	4	167000.0317
	Ne II ($P^\circ_{3/2}$)	Limit		173929.75

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Table 3.4 Persistent lines of neutral sodium (Na I) in the 200-850 nm region

Intensity	Wavelength (Å)	Energy Levels [low,high](cm^{-1})	Configurations	Terms
5	2852.81	0.000	3s	^2S
		35042.85	5p	$^2P^0$
2	2853.01	0.000	3s	^2S
		35040.38	5p	$^2P^0$
15	3302.37	0.000	3s	^2S
		30272.58	4p	$^2P^0$
8	3302.98	0.000	3s	^2S
		30266.99	4p	$^2P^0$
1000	5889.950	0.000	3s	^2S
		16973.368	3p	$^2P^0$
500	5895.924	0.000	3s	^2S
		16956.172	3p	$^2P^0$
60	8183.256	16956.172	3p	$^2P^0$
		29172.889	3d	^2D
10	8194.790	16973.368	3p	$^2P^0$
		29172.889	3d	^2D

Table 3.5 Persistent lines of neutral mercury (Hg I) in 200-850 nm region

Intensity	Wavelength (Å)	Energy Levels [low,high](cm^{-1})	Configurations	Terms
1000	1849.499	0.000	$5d^{10}(^1S)6s^2$	6^1S
		54068.781	$5d^{10}(^1S)6s6p$	$^1P^0$
1000	2536.517	0.000	$5d^{10}(^1S)6s2$	^1S
		39412.300	$5d^{10}(^1S)6s6p$	$^3P^0$
250	2967.280	37645.080	$5d^{10}(^1S)6s6p$	$^3P^0$
		71336.164	$5d^{10}(^1S)6s6d$	(1/2,3/2)
600	3650.153	44042.977	$5d^{10}(^1S)6s6p$	$^3P^0$
		71431.311	$5d^{10}(^1S)6s6d$	(1/2,5/2)
400	4046.563	37645.080	$5d^{10}(^1S)6s6p$	$^3P^0$
		62350.456	$5d^{10}(^1S)6s7s$	^3S
1000	4358.328	39412.300	$5d^{10}(^1S)6s6p$	$^3P^0$
		62350.456	$5d^{10}(^1S)6s7s$	^3S

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500	5460.735	44042.977	$5d^{10}(^1S)6s6p$	$^3P^0$
		62350.456	$5d^{10}(^1S)6s7s$	^3S
50	5769.598			
60	5790.663			
200	10139.76	54068.781	$5d^{10}(^1S)6s6p$	$^1P^0$
		63928.243	$5d^{10}(^1S)6s7s$	^1S

Table 3.6 Persistent lines of neutral mercury (Hg I) in 200-850 nm region

Intensity	Wavelength (Å)	Energy Levels [low,high](cm^{-1})	Configurations	Terms
100	3520.4711	135888.7173	$2p^5\ (^2P^0_{1/2})3s$	$^2[1/2]^0$
		164285.8872	$2p^5\ (^2P^0_{1/2})4p$	$^2[1/2]$
200	5400.5618	134459.2871	$2p^5\ (^2P^0_{3/2})3s$	$^2[3/2]^0$
		152970.7328	$2p^5\ (^2P^0_{1/2})3p$	$^2[1/2]$
200	5852.4879	135888.7173	$2p^5\ (^2P^0_{1/2})3s$	$^2[1/2]^0$
		152970.7328	$2p^5\ (^2P^0_{1/2})3p$	$^2[1/2]$
100	6029.9969	134459.2871	$2p^5\ (^2P^0_{3/2})3s$	$^2[3/2]^0$
		151038.4524	$2p^5\ (^2P^0_{1/2})3p$	$^2[1/2]$
100	6074.3377	134459.2871	$2p^5\ (^2P^0_{3/2})3s$	$^2[3/2]^0$
		150917.4307	$2p^5\ (^2P^0_{3/2})3p$	$^2[1/2]$
100	6143.0626	134041.8400	$2p^5\ (^2P^0_{3/2})3s$	$^2[3/2]^0$
		150315.8612	$2p^5\ (^2P^0_{3/2})3p$	$^2[3/2]$
100	6163.5939	134818.6405	$2p^5\ (^2P^0_{1/2})3s$	$^2[1/2]^0$
		151038.4524	$2p^5\ (^2P^0_{1/2})3p$	$^2[1/2]$
100	6217.2812	134041.8400	$2p^5\ (^2P^0_{3/2})3s$	$^2[3/2]^0$
		150121.5922	$2p^5\ (^2P^0_{3/2})3p$	$^2[3/2]$
100	6266.4950	134818.6405	$2p^5\ (^2P^0_{1/2})3s$	$^2[1/2]^0$
		150772.1118	$2p^5\ (^2P^0_{1/2})3p$	$^2[3/2]$
100	6382.9917	134459.2871	$2p^5\ (^2P^0_{3/2})3s$	$^2[3/2]^0$
		150121.5922	$2p^5\ (^2P^0_{3/2})3p$	$^2[3/2]$
200	6402.248	134041.8400	$2p^5\ (^2P^0_{3/2})3s$	$^2[3/2]$
		149657.0393	$2p^5\ (^2P^0_{3/2})3p$	$^2[3/2]^0$
150	6506.5281	134459.2871	$2p^5\ (^2P^0_{3/2})3s$	$^2[5/2]$
		149824.2215	$2p^5\ (^2P^0_{3/2})3p$	$^2[3/2]^0$
100	6598.9529	135888.7173	$2p^5\ (^2P^0_{1/2})3s$	$^2[5/2]$
		151038.4524	$2p^5\ (^2P^0_{1/2})3p$	$^2[1/2]^0$
1000	6929.4673	135888.7173	$2p^5\ (^2P^0_{1/2})3s$	$^2[1/2]^0$

		150315.8612	$2p^5\ (^2P^0_{3/2})3p$	$^2[3/2]$
800	7032.4131	134041.8400	$2p^5\ (^2P^0_{3/2})3s$	$^2[3/2]^0$
		148257.7898	$2p^5\ (^2P^0_{3/2})3p$	$^2[1/2]$
800	7173.9381	135888.7173	$2p^5\ (^2P^0_{1/2})3s$	$^2[1/2]^0$
		149824.2215	$2p^5\ (^2P^0_{3/2})3p$	$^2[5/2]$
800	7245.1666	134459.2871	$2p^5\ (^2P^0_{3/2})3s$	$^2[3/2]^0$
		148257.7898	$2p^5\ (^2P^0_{3/2})3p$	$^2[1/2]$
800	8377.6080	149657.0393	$2p^5\ (^2P^0_{3/2})3p$	$^2[5/2]$
		161590.3412	$2p^5\ (^2P^0_{3/2})3d$	$^2[7/2]^0$

Table 3.7 Spectrometer data for lines in known light sources and the data for matching lines in the standard spectrum for the known element.

Ligh Source	Lines in experimental spectrum			Matching lines in standard spectrum			Identification of Transition				
							Upper level		Lower level		Emitted light Wavelength (nm)
	Pixel number	Wavelength λ (nm)	Intensity counts	Element	Wavelength λ (nm)	Intensity	Configuration	Energy $E_l cm^{-1}$	Configuration	Energy $E^2 cm^{-1}$	
Sodium Lamp	1139	589.76	3897.00	Na	588.99	1000	$3^2P_{3/2}$	16973.37	$3^2S_{1/2}$	0	589.16
	1141	590.43	3943.00		589.59	500	$3^2P_{1/2}$	16956.17	$3^2S_{1/2}$	0	589.76
Mercury Lamp	502	365.45	1189.667	Hg	365.02	600	(1/2,5/2)	71431.31	$6^3P^0_2$	44042.98	365.12
	611	404.97	818.667		404.66	400	7^3S_1	62350.46	$6^3P^0_0$	37645.08	404.77
	698	436.20	1832.333		435.83	1000	7^3S1	62350.46	$6^3P^0_1$	39412.30	435.95
	1013	546.71	4026.000		546.07	500	7^3S_1	62350.46	$6^3P^0_2$	44042.98	546.22
	1103	577.53	1529.667		576.96	50					
	1109	579.57	1573.667		579.07	60					
He-Ne Laser	1269	633.42	4095.000	Ne	638.30	100	2[3/2]	150121.59	$^2[3/2]^0$	134459.29	638.48

Table 3.8 Spectrometer data for lines in unknown light sources and the data for matching lines in the standard spectrum for the known element.

Light Source	Lines in experimental spectrum			Matching lines in standard spectrum			Identification of Transition				
	Pixel number	Wavelength λ (nm)	Intensity counts	Element	Wavelength λ (nm)	Intensity	Upper level		Lower level		Emitted light Wavelength (nm)
							Configuration	Energy $E_l cm^{-1}$	Configuration	Energy $E^2 cm^{-1}$	
Tube light	502	365.45	269	Hg	365.02	600	(1/2,5/2)	71431.31	$6^3P^0_2$	44042.98	365.12
	611	404.97	1049		404.66	400	7^3s_1	62350.46	$6^3P^0_0$	37645.08	404.77
	698	436.20	3495		435.83	1000	7^3s_1	62350.46	$6^3P^0_1$	39412.30	435.95
	1012	546.37	3066		546.07	500	7^3s_1	62350.46	$6^3P^0_2$	44042.98	546.22
	1103	577.53	941		576.96	50					
	1108	579.23	953		579.07	60					
CFL	501	365.06	106	Hg	365.02	600	(1/2,5/2)	71431.31	6^3P^0	44042.97	
	610	404.61	733		404.66	400	7^3s_1	2350.46	$6^3P^0_0$	37645.08	404.77
	697	435.84	2554		435.83	1000	73s1	62350.46	$6^3P^0_1$	39412.30	435.95
	842	487.22	805		---						
	999	541.89	2398								
	1011	546.03	3969		546.07	500	7^3s_1	62350.46	$6^3P^0_2$	44042.98	546.22
	1102	577.19	603		576.96	50					
	1108	579.23	669		579.07	60					
	1204	611.68	2466								

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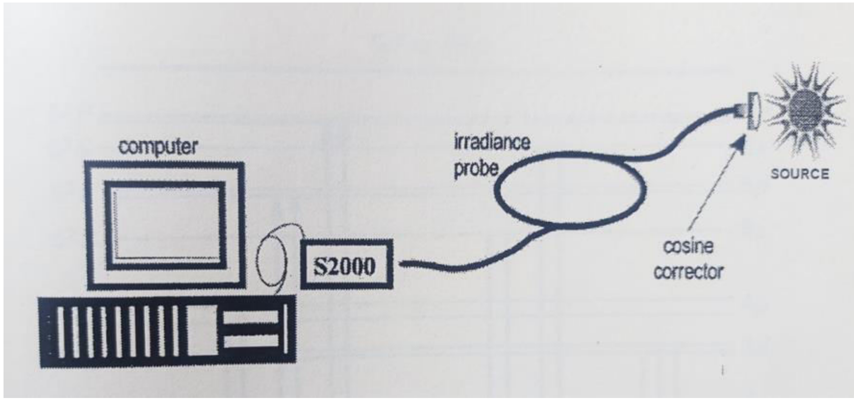

Figure 3.1 Fibre optic spectrometer configuration for recording source spectrum (emission spectrum)

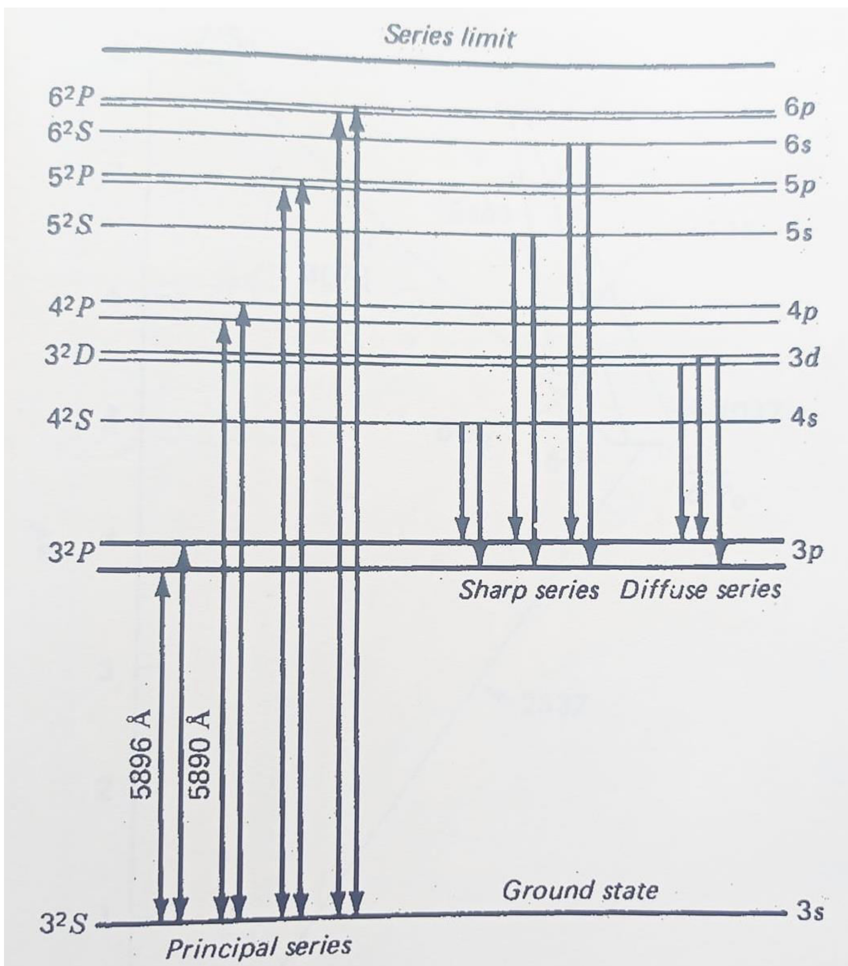

Figure 3.2 Energy level diagram for sodium atom showing transitions for the first members of the Sharp, Principle and Diffuse series.
[Reference: Fundamentals of optics, Jenkins & White]

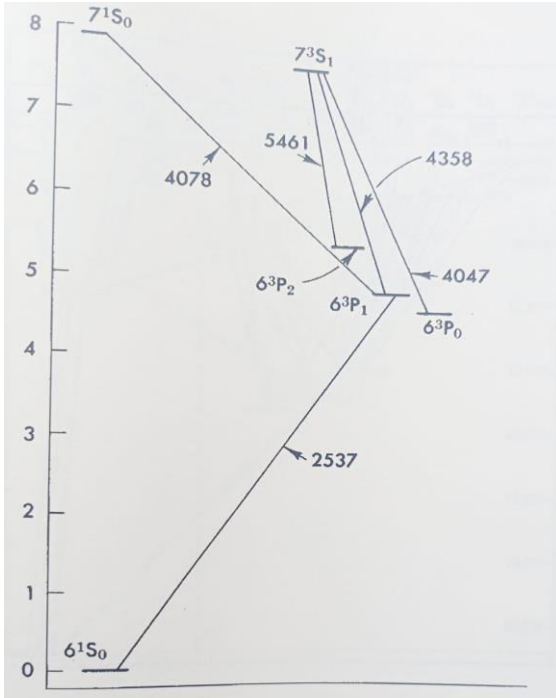

Figure 3.3a Energy level diagram for mercury atom showing some of the transitions leading to bright lines in the spectrum.
[Reference: Experimental Physics,Mellisnos]

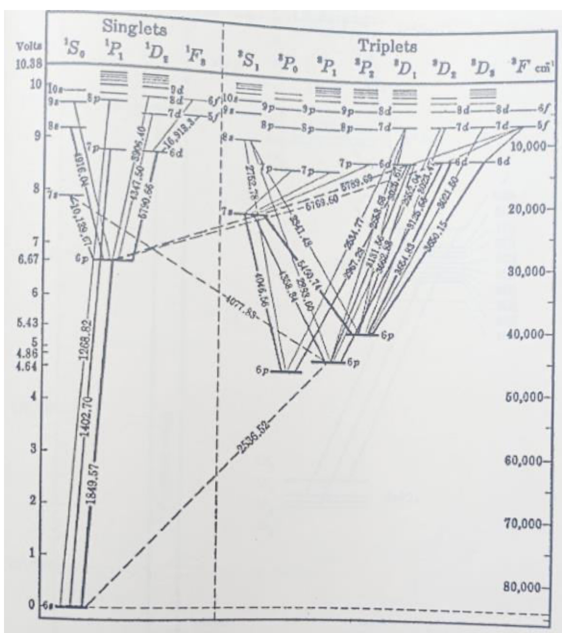

Figure 3.3b Energy level diagram for mercury atom showing some of the transitions.
[Reference: Molecular Spectra, Vol.1, G. Herzberg]

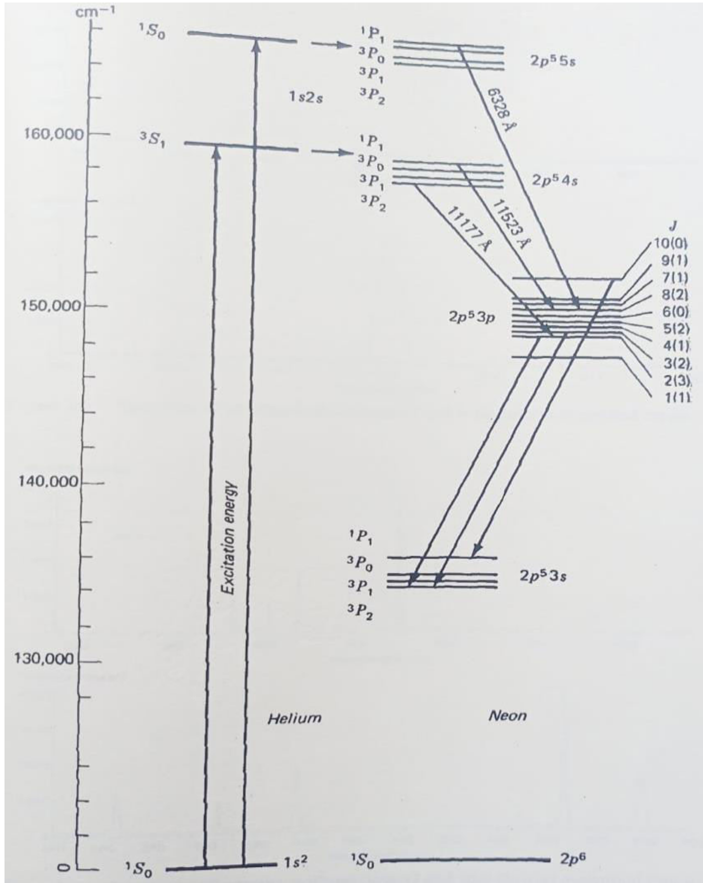

Figure 3.4 Energy level diagram for He-Ne laser showing some of the transitions. [Reference: Fundamentals of optics, Jenkins & White]

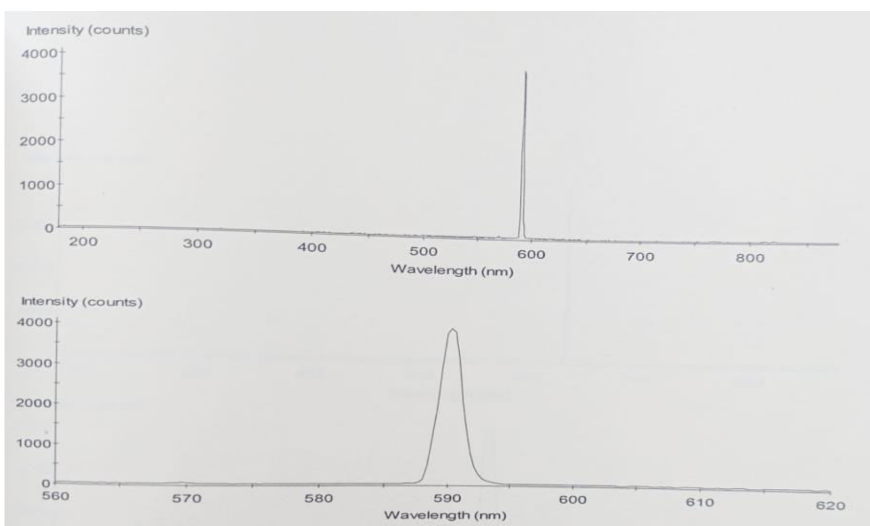

Figure 3.5 Spectrum of sodium without (upper) and with (lower) magnified range.

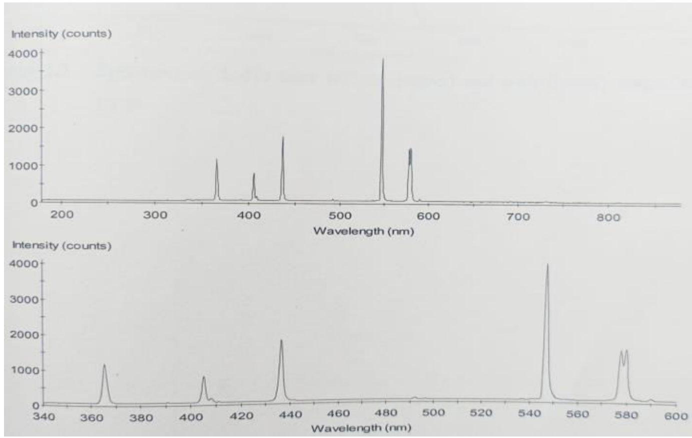

Figure 3.6 Spectrum of mercury without (upper) and with (lower) magnified range.

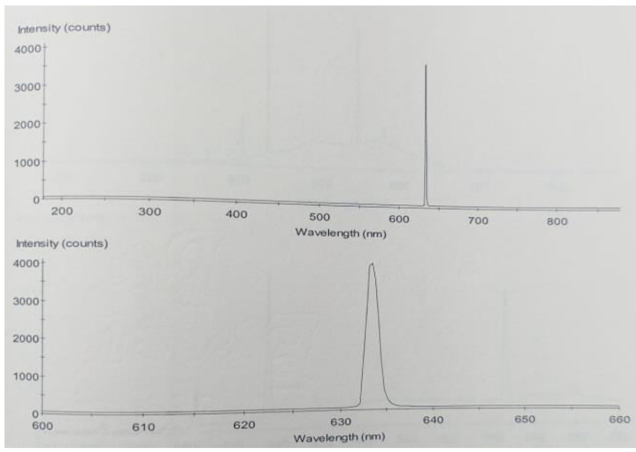

Figure 3.7 Spectrum of He-Ne laser without (upper) and with (lower) magnified range.

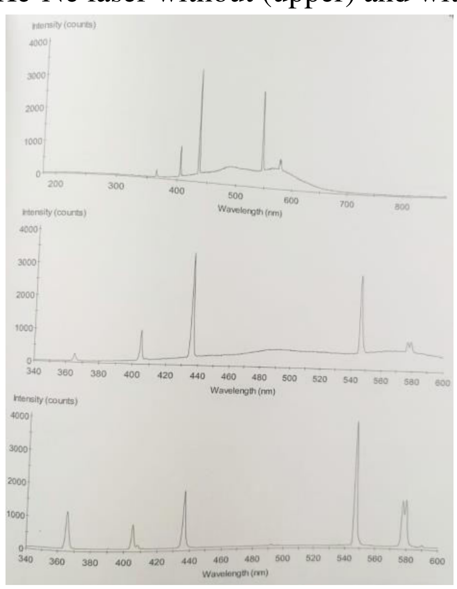

Figure 3.8 Spectrum of tube light without (top) and with (middle) magnified range. The spectrum of mercury lamp (from Figure 3.5) at the bottom is given again here for convenience of comparison.

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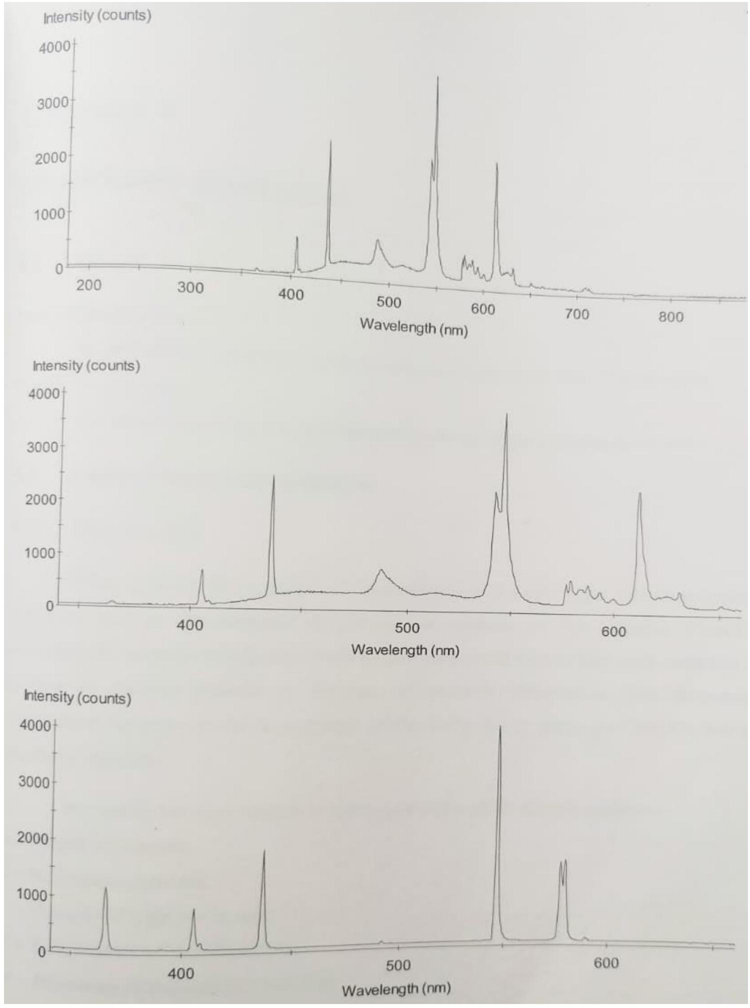

Figure 3.9 Spectrum of cold fluorescent lamp (CFL) without (top) and with (middle) magnified range. The spectrum of mercury lamp (from Figure 3.5) at the bottom is given again here for convenience of comparison.