

# **CHAPTER – III**

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### 3 PREPARATION AND CHARACTERIZATION OF Cu (II) COMPLEXES

#### 3.1 Introduction

The transition elements play important roles in our daily life and in keeping the living organisms alive. Many materials that we encounter each day contain transition elements such as iron, copper, chromium, nickel etc. in one form or the other. Production of various materials using chemical processes invariably involves catalysts which are mostly transition metals and their compounds. In order to understand roles of transition elements in biological systems or in chemical processes involving them, it is essential to understand the principles underlying the chemistry of these elements. Transition metals have relatively high densities, high melting and boiling points, and high heats of fusion and vaporization.

The chemical elements in the periodic table are arranged together in blocks according to their outer electronic configurations. The elements with a half-filled or fully-filled outer s orbital comprise the s-block elements. Similarly, the elements with partly filled or fully filled outer p orbitals comprise the p-block elements. The elements between two blocks in the periodic table have at most two electrons in the outermost s orbital, and incompletely filled d orbitals next to outermost orbital. These elements in which successive addition of electrons takes place progressively in the inner d orbitals are called as d- block elements. Similarly, the elements in which filling up of electrons takes place in inner to inner f orbitals are known as f-block elements. These two blocks of elements are generally called transition elements. However, the f-block elements are commonly known as inner transition elements. The electronic configurations of the valence shells of the d-block elements can be given as  $(n-1)d^{1-10}ns^{1-2}$ , where (n-1) stands for the inner d orbitals. It is observed that the electron first enters in higher principal quantum number orbital (n) rather than in unoccupied (n-1)d orbital.

Many transition metal ions are coloured due to d-d transitions. The energy absorbed in excitation of an electron from a lower energy d orbital to a higher

energy d orbital corresponds to the frequency which generally lies in the visible region. The colour observed corresponds to the complementary colour of the light absorbed. The frequency of light absorbed is determined by the nature of ligand. The transition metals and their ions have much higher tendency to form coordination compounds as compared to the s- and p- block elements. It is

Because of their relatively smaller sizes, higher ionic charges and the availability of d orbitals for bond formation.

A characteristic feature of the transition metals is their ability to form a group of compounds called coordination compounds, complex compounds, or sometimes simply complexes. Coordination compounds are formed between a metal atom or ion and a molecule with one or more unshared electron pairs, called a ligand.

Coordination Chemistry is the chemistry of coordination compounds or metal complexes. A coordination compound consists of a central metal ion surrounded by a certain number of ligands. These ligands can be simple inorganic anions (F<sup>-</sup>, Cl<sup>-</sup>, Br<sup>-</sup>, I<sup>-</sup>, NO<sub>3</sub><sup>-</sup>, SO<sub>4</sub><sup>-</sup>, ...) or molecules (H<sub>2</sub>O, NH<sub>3</sub>, ...), but also large organic molecules can act as ligands. The ligands are bound via so-called dative or coordinative bonds to the central metal ion. The ligands don't really need the metal to complete their valence shell, but the interaction with the metal ion will result nevertheless in a coordination compound, which is more stable than the metal ion and the ligands separately. Because the central metal ion is very often a d-block element (transition metals) or an f-block element (lanthanides and actinides), coordination chemistry is for many scientists a synonym for the chemistry of the transition metals, lanthanides and actinides.

The chelating abilities of Schiff bases and their analytical applications have attracted remarkable attention<sup>119</sup>. o- Phenylenediamine (O-PDA) is used in the copper catalyzed synthesis of quinoxalines (Wang W., et al, 2011). O-PDA is also suitable for removing elemental sulfur in mining ores, and removing aldehyde colour formers in polymers. Polymeric plasticized membrane electrode based on Bis-(o-phenylenediamine)-Cu (II) (Cu (II)BOPD) complex has been investigated as iodide selective electrode exhibiting anti-Hofmeister selectivity pattern<sup>120</sup>. Moreover, it is used as a pharmaceutical intermediate in pharmaceuticals

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<sup>119</sup> Ramana. N., L.Mitub, A. Sakthivela, M.S.S. Pandia, *J. Iran.Chem. Soc.*, **6(4)**, 738, (2009).  
Theis B., S. Metz, F. Back, C. Burschka, R. Tacke, *Zanorg. allg. Chem.*, **635**, 1306 (2009).

<sup>120</sup> Rawat A. S. Chandra, A. Sarkar, *Sensor Letters*, **8(6)**, 753, (2010).

industry<sup>121</sup>. Schiff bases of (O-PDA) are used in the synthesis of insecticides, dyestuff fungicides, corrosion inhibitors and pigments. A large number of Schiff bases and their complexes are of significant interest and attention is drawn to them because of their biological activity including anti-tumor, antibacterial, fungicidal and anti-carcinogenic properties<sup>122</sup>.

Due to the diverse applications of both types of derivatives, their metal complexes have been synthesized. Transition metal ions plays vital role in a vast number of biological processes and ions with biologically active ligands are subject of considerable interest. Present work deals with synthesis and characterization of Cu (II) complexes. Sample preparation was carried out by chemical root method. After the sample preparation different characterization techniques to characterized samples were applied like XRD and FTIR. X-ray spectroscopy techniques includes near edge and X-ray fine structure studies. In addition, all these studies support each other and help to propose the geometry of prepared molecule.

Sample preparation is carried out by chemical root method. After the sample preparation different characterization techniques to characterize the samples were applied like X-ray diffraction, fourier transform infrared and X-ray absorption spectroscopy techniques. The XRD patterns were recorded on Bruker D8 Advanced X-ray diffractometer. XRD and FTIR both characterizations were done in IUC, DAE, Indore. In addition, all these studies support each other and help to propose the geometry of prepared molecule.

## **3.2 Synthesis of ligand and its metal complexes**

### **3.2.1 Synthesis of ligand**

#### **Step I**

Pertinent aniline derivatives were dissolved in 16.0ml HCl and 16.0ml distilled water and kept at freezing temperature in the refrigerator .To this, an aqueous solution of sodium nitrite (3.45 g.) in 17ml of distilled water was added drop wise with continuous stirring keeping the temperature in the vicinity of 0-5°C. Meanwhile, in another beaker Acetyl acetone (5.13 ml), sodium acetate (4.10 gm)

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<sup>121</sup> Gangani B.J. ,P.H. Parsania , *Spectrosc. Lett.*, **40** , 97, (2007).

<sup>122</sup> Sadeek S.A. , M.S. Refaat., *Journal of the Korean Chemical Society*, **50(2)** , 107, (2006)

and 22 ml of ethanol were taken and cooled in an ice bath. Now the diazotized solution was added to the solution of Acetyl acetone and sodium acetate drop wise with constant stirring under temperature-controlled conditions. The reaction mixture was kept for reflux for 5-6 hours and then it was filtered through suction and dried in vacuum. Now the fine crystals of the compound (couple product) were obtained below<sup>123</sup>.

### **Step II**

To a solution of couple product, Ethanol (50 ml) and orthophenylenediamine was added in equimolar ratio. The reaction mixture was refluxed for 4-5 hours and the solid product formed which was filtered off and crystallized from ethanol.

### **3.2.2 Synthesis of complexes**

In a 250ml round bottom flask equimolar ethanol solution of ligand and  $M-Cl_2$  were taken and this mixture was refluxed for 4 hours. After reflux Solvent was evaporated to afford fine crystal of Bis-pentanyl R- phenyldiazine Cu(II) bis-benzenediamine chloride complexes. This was recrystallized from ethanol.<sup>124</sup>. Chemical reaction for synthesis of the above complex is given in fig. 3.1.

Formation of the metal complexes can be represented by the following general equations  $MX_2 + 2L \rightarrow M(L)_2 + 2X$ . In this equation, M is Cu (II) and X is Cl and L is Bis-pentanyl R- phenyldiazine Cu(II) bis-benzenediamine where R shows that 3-Cl, P-N, 4-Br, 2-Cl, 2-n, O-N etc. Synthesized Copper (II) complexes their abbreviations and molecular formulae are given in table 3.1.

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<sup>123</sup> Ramana. N., L.Mitub, A. Sakthivela, M.S.S. Pandia, *J. Iran. Chem. Soc.*, **6(4)**, 738, (2009).

<sup>124</sup> Ramana. N., L.Mitub, A. Sakthivela, M.S.S. Pandia, *J. Iran. Chem. Soc.*, **6(4)**, 738, (2009).

<b>Table 3.1</b> Copper (II) complexes, abbreviation and molecular formula.			
<b>S.No.</b>	<b>Complex name</b>	<b>Abbreviation</b>	<b>Molecular formula</b>
1.	Bis-pentanyl R(4-Nitro)-phenyldiazine Cu(II) bis-benzenediamine	Bisp(4-Nitro)pdCu(II)bisbd	$C_{32}H_{26}N_{10}O_4Cl_2Cu$
2.	Bis-pentanyl R(pure anilene)- phenyldiazine Cu(II) bis-benzenediamine	Bisp(pure anilene)pdCu(II)bisbd	$C_{32}H_{28}N_8Cl_2Cu$
3.	Bis-pentanyl R(2-anisidine)- phenyldiazine Cu(II) bis-benzenediamine	Bisp(2-anisidine)pdCu(II)bisbd	$C_{34}H_{32}N_8O_2Cl_2Cu$
4.	Bis-pentanyl R(4-chloro)-phenyldiazine Cu(II) bis-benzenediamine	Bisp(4-chloro)pdCu(II)bisbd	$C_{32}H_{26}N_8Cl_4Cu$
5.	Bis-pentanyl R(4-Bromo)-phenyldiazine Cu(II) bis-benzenediamine	Bisp(4-Bromo)pdCu(II)bisbd	$C_{32}H_{26}N_8Cl_2Br_2Cu$
6.	Bis-pentanyl R(2-chloro)-phenyldiazine Cu(II) bis-benzenediamine	Bisp(2-chloro)pdCu(II)bisbd	$C_{32}H_{26}N_8Cl_4Cu$
7.	Bis-pentanyl R(3-Nitro)-phenyldiazine Cu(II) bis-benzenediamine	Bisp(3-Nitro)pdCu(II)bisbd	$C_{32}H_{26}N_{10}O_4Cl_2Cu$
8.	Bis-pentanyl R(2-Nitro)-phenyldiazine Cu(II) bis-benzenediamine	Bisp(2-Nitro)pdCu(II)bisbd	$C_{32}H_{26}N_{10}O_4Cl_2Cu$
9.	Bis-pentanyl R(4-anisidine)- phenyldiazine Cu(II) bis-benzenediamine	Bisp(4-anisidine)pdCu(II)bisbd	$C_{32}H_{26}N_8Cl_4Cu$
10.	Bis-pentanyl R(Aceto-p-Toludine)- phenyldiazine Cu(II) bis-benzenediamine	Bisp(Aceto-p-Toludine)pdCu(II)bisbd	$C_{36}H_{32}N_8O_2Cl_2Cu$

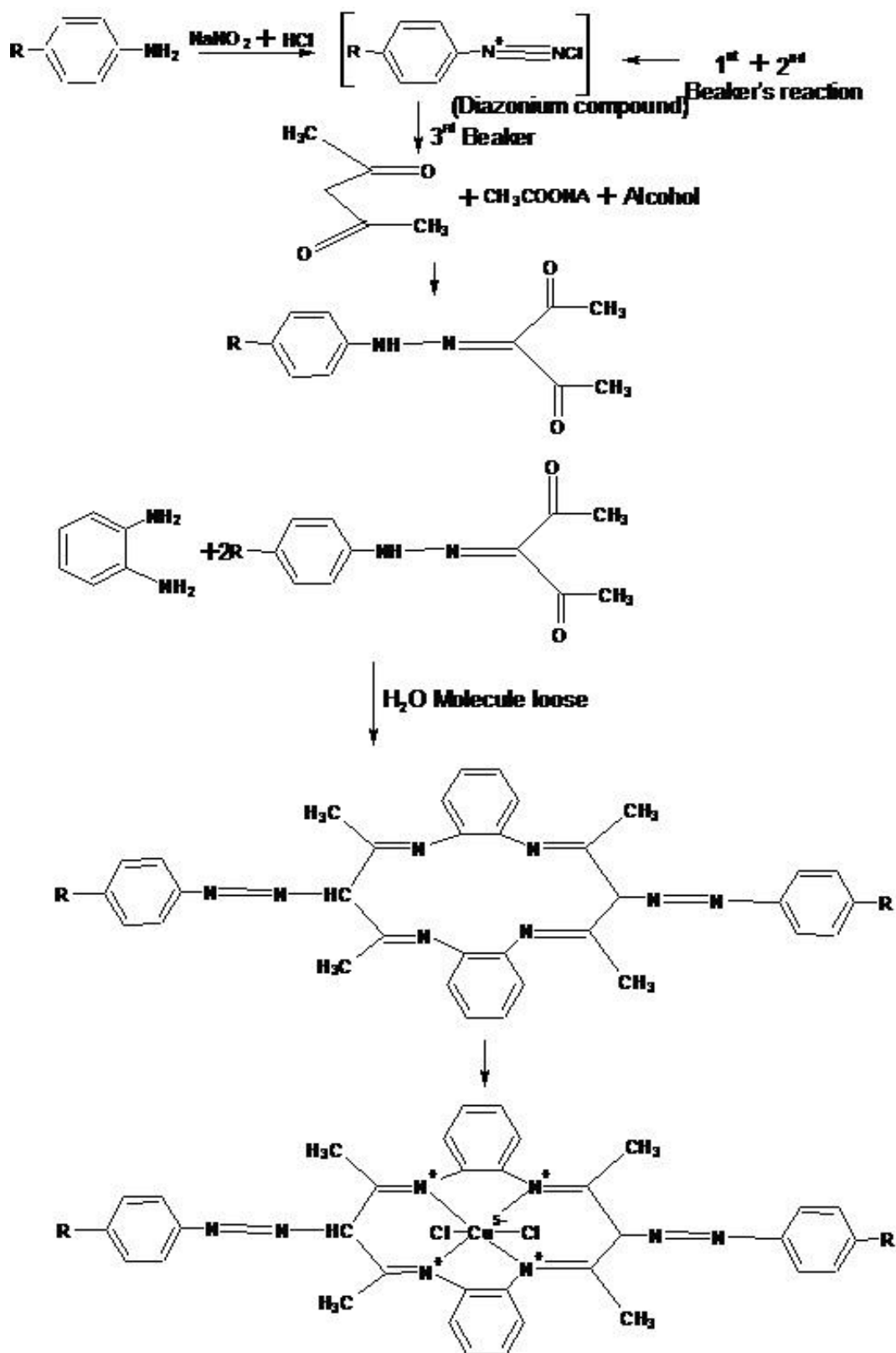


Figure 3-1 Complete synthesis schemes of copper (II) complexes.

### 3.3 Structural characterization metal complexes

#### 3.3.1 X-ray Diffraction Study (XRD)

##### 3.3.1.1 (a) Copper Complexes

For X-ray diffraction studies Bruker D8 advance Diffractometer was used. X-ray diffractometer D8 Advance of Bruker AXS is a versatile tool for phase and structural analysis of powders, analysis of liquid samples (capillary and transmission modes) and reflectometry of thin layers.

X-ray powder diffraction patterns of the samples were recorded at room temperature using Cu K $\alpha$  radiation and also shown in figure 3.2. The diffraction patterns of samples recorded between 2 $\theta$  ranging from 0° to 50°. The diffraction patterns have been successfully indexed and the values of different parameters are shown in table 3.2(a-e). Values of unit cell volume, angle  $\beta$  and lattice parameters of samples are shown in table 3.3.

X-ray powder diffraction patterns of the complexes are indicative of their crystalline nature and had a monoclinic crystal lattice. In some cases deviation between the calculated and observed  $d$  values was nearly equal to one, which indicates that the synthesized complexes are multiphase complexes<sup>125</sup>. Interplanar  $d$  spacing and unit cell volume of the synthesized complexes were calculated by the formulae:

$$\frac{1}{d^2} = \frac{1}{\sin^2 \beta} \left[ \frac{h^2}{a^2} + \frac{k^2 * \sin^2 \beta}{b^2} + \frac{l^2}{c^2} - \frac{2hlc \cos \beta}{a * c} \right]$$

And volume

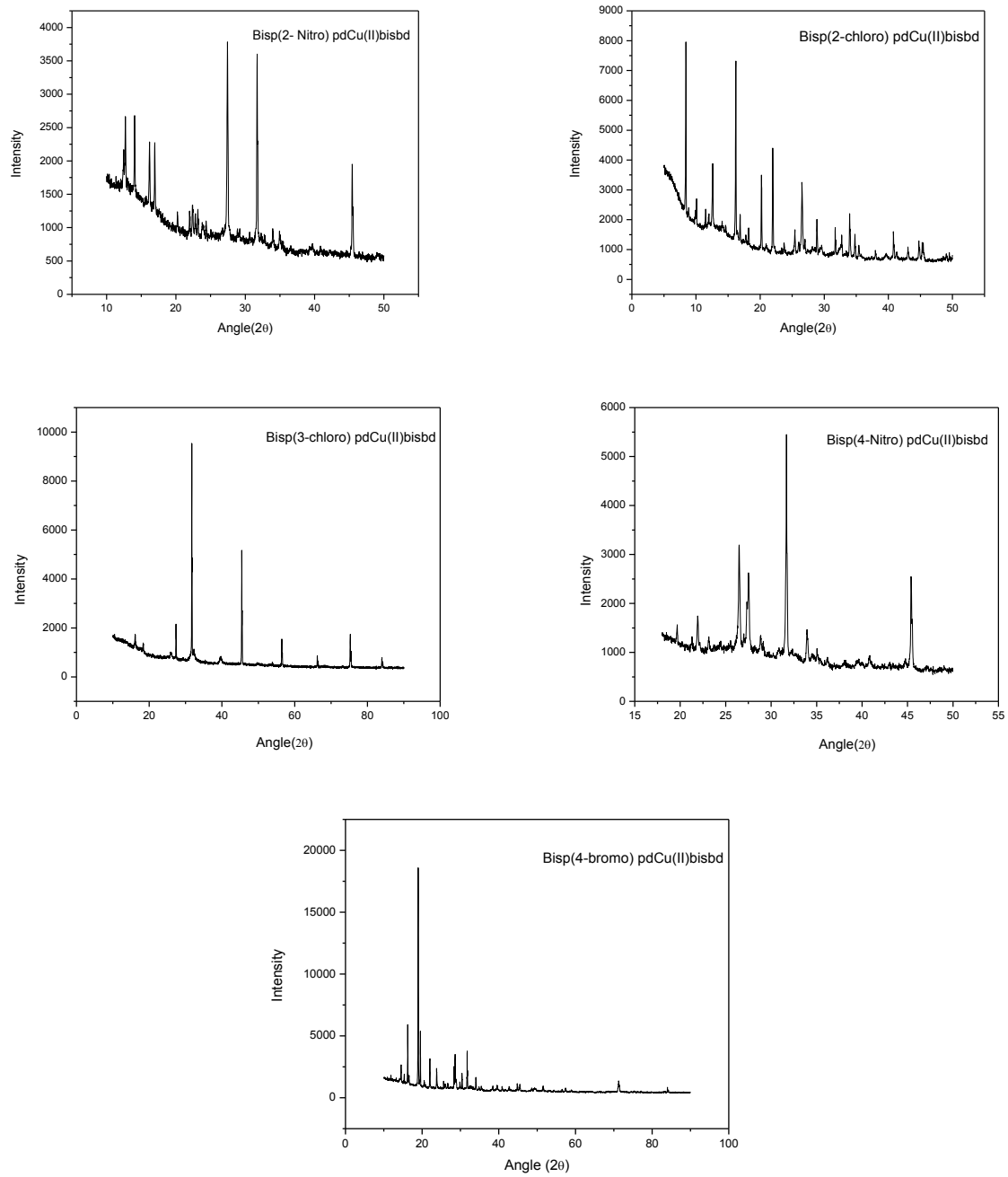
$$V = abc \sin \beta.$$

As our synthesized samples are complexes, and due to the lone pair of electrons, distortion occurs due to which it undergoes lower symmetry, yet the characteristic and prominent peaks of complexes and the crystal system have been identified, which are equal and in some cases nearly match the standard diffraction card JCPDS also shown.

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<sup>125</sup> Chauhan H. P. S., Bakshi A., J Therm Anal Calorim, (2011), 105, 937–946.





**Figure 3-2 XRD patterns for copper (II) complexes**

**Table 3.2 The observed and the calculated data for X-ray diffraction pattern of**

<b>Table 3.2(a):</b> The observed and the calculated data for X-ray diffraction pattern of the <b>Bis-pentanyl R(2- Nitro)- phenyldiazine Cu(II) benzenediamine,(S1)</b> JCPDS CARD NO. (771144, 321607, 502052, 271608, 522496, 730106)						
<b>2 theta (in degree)</b>	<b>d-spacing observed ( in Å )</b>	<b>d-spacing calculated ( in Å )</b>	<b>Relative Intensity (%)</b>	<b>h</b>	<b>k</b>	<b>l</b>
<b>12.68</b>	<b>6.97</b>	<b>6.71</b>	<b>69.5</b>	<b>0</b>	<b>1</b>	<b>1</b>
<b>14.06</b>	<b>6.29</b>	<b>6.27</b>	<b>72.33</b>	<b>2</b>	<b>0</b>	<b>0</b>
<b>16.15</b>	<b>5.46</b>	<b>5.48</b>	<b>58.86</b>	<b>0</b>	<b>2</b>	<b>0</b>
<b>27.27</b>	<b>3.35</b>	<b>4.12</b>	<b>100</b>	<b>0</b>	<b>4</b>	<b>0</b>
<b>31.69</b>	<b>2.81</b>	<b>2.09</b>	<b>96.40</b>	<b>6</b>	<b>0</b>	<b>0</b>
<b>42.47</b>	<b>2.12</b>	<b>2.11</b>	<b>12.46</b>	<b>0</b>	<b>0</b>	<b>4</b>
<b>45.44</b>	<b>1.90</b>	<b>1.67</b>	<b>51.83</b>	<b>1</b>	<b>1</b>	<b>5</b>

the cu (II) complexes

<b>Table 3.2(b):</b> The observed and the calculated data for X- ray diffraction pattern of the <b>Bis-pentanyl R(2- chloro)- phenyldiazine Cu(II) bis-benzenediamine (S2)</b> JCPDS CARD NO. (771144, 321607, 502052, 271608, 522496, 730106)						
<b>2 theta (in degree)</b>	<b>d-spacing observed ( in Å )</b>	<b>d-spacing calculated ( in Å )</b>	<b>Relative Intensity (%)</b>	<b>h</b>	<b>k</b>	<b>l</b>
<b>8.45</b>	<b>10.48</b>	<b>10.48</b>	<b>100</b>	<b>0</b>	<b>0</b>	<b>1</b>
<b>12.60</b>	<b>7.01</b>	<b>7.50</b>	<b>49.76</b>	<b>0</b>	<b>1</b>	<b>1</b>
<b>16.19</b>	<b>5.46</b>	<b>5.47</b>	<b>92.55</b>	<b>0</b>	<b>2</b>	<b>0</b>
<b>20.23</b>	<b>4.25</b>	<b>5.24</b>	<b>43.22</b>	<b>0</b>	<b>0</b>	<b>2</b>
<b>21.96</b>	<b>4.04</b>	<b>4.04</b>	<b>57.20</b>	<b>2</b>	<b>0</b>	<b>0</b>
<b>26.48</b>	<b>3.36</b>	<b>3.79</b>	<b>40.48</b>	<b>-2</b>	<b>1</b>	<b>0</b>
<b>31.66</b>	<b>2.81</b>	<b>2.39</b>	<b>22.77</b>	<b>-3</b>	<b>0</b>	<b>2</b>
<b>33.98</b>	<b>2.63</b>	<b>2.69</b>	<b>29.31</b>	<b>3</b>	<b>0</b>	<b>0</b>

**Table 3.2(c):** The observed and the calculated data for X-ray diffraction pattern of the **Bis-pentanyl R(3- chloro)- phenyldiazine Cu(II) bis-benzenediamine (S3)**JCPDS CARD NO. (771144, 321607, 502052, 271608, 522496, 730106)

2 theta (in degree)	d-spacing observed ( in Å )	d-spacing calculated ( in Å )	Relative Intensity (%)	h	k	l
16.00	5.53	5.48	20.02	0	0	2
27.54	3.23	3.23	23.93	0	4	0
31.76	2.81	2.78	100	6	0	0
45.40	2.02	2.20	54.19	1	1	5
56.33	1.63	1.85	17.08	9	1	1
66.19	1.41	2.03	9.27	5	5	1

**Table 3.2(d):** The observed and the calculated data for X-ray diffraction pattern of the **Bis-pentanyl R(4- Nitro)- phenyldiazine Cu(II) bis-benzenediamine (S4)** JCPDS CARD NO. (771144, 321607, 502052, 271608, 522496, 730106, 140991)

2 theta (in degree)	d-spacing observed ( in Å )	d-spacing calculated ( in Å )	Relative Intensity (%)	h	k	l
19.68	4.50	4.5	29.22	0	0	2
21.94	4.04	4.04	31.73	0	2	0
26.46	3.36	3.9	59.04	1	2	0
27.48	3.23	2.82	49.70	-2	2	2
31.54	2.71	2.71	100	6	0	0
33.96	2.63	2.28	27.46	1	3	2
34.08	2.62	2.69	29.22	3	3	0
45.39	1.99	2.10	47.96	4	3	1

**Table 3.2(e):** The observed and the calculated data for X-ray diffraction pattern of the **Bis-pentanyl R(4-bromo)- phenyldiazine Cu(II) bis-benzenediamine (S6)** JCPDS CARD NO. (771144, 321607, 502052, 271608, 522496, 730106)

2 theta (in degree)	d-spacing observed (in Å)	d-spacing calculated (in Å)	Relative Intensity (%)	h	k	l
14.52	6.09	6.09	15.95	2	0	0
16.21	5.46	5.46	31.53	0	2	0
18.92	4.68	4.68	100	0	0	4
22.07	4.02	3.73	17.04	-3	1	1
28.60	3.11	3.91	18.05	2	1	1
30.29	2.94	2.73	21.22	0	4	0
31.76	2.81	2.03	22.21	6	0	0

**Table 3.3 Values of unit cell volume, angle  $\beta$  and lattice parameters of samples**

Sample Name	Unit Cell Volume ( $10^{-8}\text{cm}^3$ )	Angle $\beta$ (in degree)	Lattice Parameters		
			a	b	c
Bisp(2- Nitro)pdCu(II)bisbd	1169.182	90.26	12.58	10.96	8.48
Bisp(2- chloro)pdCu(II)bisbd	922.863	93.60	8.08	10.92	10.48
Bisp(3-chloro)pdCu(II)bisbd	1962.10	125.47	16.86	12.92	11.06
Bisp(4- Nitro) pdCu(II)bisbd	1182.247	90.26	16.26	8.08	9.00
Bisp(4-chloro) pdCu(II)bisbd	1020.070	93.60	8.12	11.72	10.74
Bisp(4-bromo) pdCu(II)bisbd	2027.800	125.47	12.18	10.92	18.72

### 3.3.1.2(b) Copper Salts

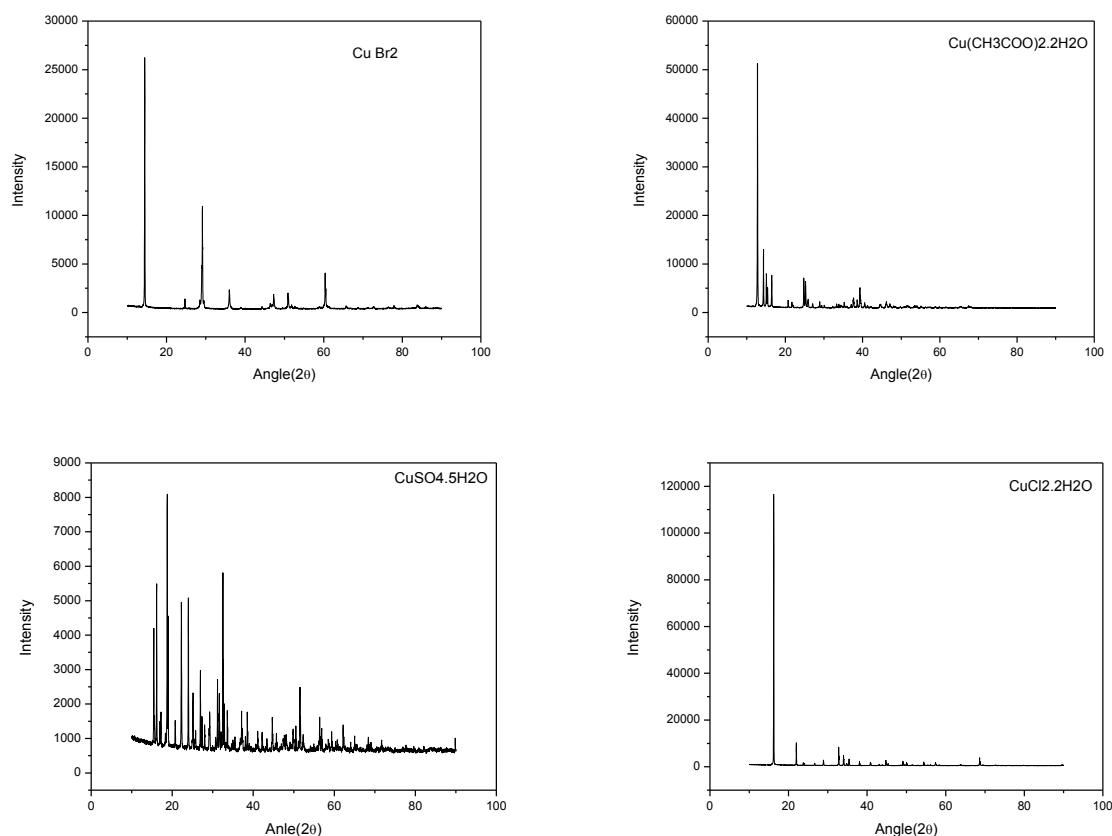
The salts were characterized at room temperature by X-ray diffraction using Cu K $\alpha$  radiation. The X-ray powder diffraction patterns of the salts are indicative of their crystalline nature. The diffraction patterns have been successfully indexed. The X-ray diffractometer records of the salts are given in figure 3.3. Particle size was calculated using Scherer's formula given by:

$$t=0.9\lambda /B\cos\theta$$

Here  $t$  is the crystal thickness (in the same units as  $\lambda$ ),  $B$  is full width half maxima (in radians) of diffraction line,  $\theta$  is the Bragg angle and  $\lambda$  is the wavelength. Lattice parameter for simple cubic crystal structure is determined by:

$$a^2 = \lambda^2 (h^2 + k^2 + l^2) / 4\sin^2\theta$$

The values of particle size and the lattice constant calculated from the diffractometer records are given in table 3.4.



**Figure 3-3 XRD patterns for copper (II) complexes**

<b>Table 3.4 Results of X-ray diffraction studies of Copper Salts</b>			
<b>Salt Name</b>	<b>Symbol</b>	<b>Particle size(in nm)</b>	<b>Lattice Parameter(in nm)</b>
<b>Cu Br<sub>2</sub></b>	<b>Salt 1</b>	<b>7.64</b>	<b>11.43</b>
<b>Cu(CH<sub>3</sub>COO)<sub>2</sub>.2H<sub>2</sub>O</b>	<b>Salt 2</b>	<b>12.35</b>	<b>12.00</b>
<b>CuSO<sub>4</sub>.5H<sub>2</sub>O</b>	<b>Salt 3</b>	<b>20.34</b>	<b>8.16</b>
<b>CuCl<sub>2</sub>.2H<sub>2</sub>O</b>	<b>Salt 4</b>	<b>21.54</b>	<b>9.6</b>

### **3.4 Fourier Transform Infrared Spectroscopy (FTIR)**

Infrared spectroscopy is certainly one of the most important analytical techniques available to today's scientists. One of the great advantages of infrared spectroscopy is that virtually any sample in virtually any state may be studied. By interpreting the infrared absorption spectrum, the chemical bonds in a molecule can be determined. FTIR spectra of pure compounds are generally so unique that they are like a molecular "fingerprint". While organic compounds have very rich detailed spectra and inorganic compounds are usually much simpler. For most common materials, the spectrum of an unknown can be identified by comparison to a library of known compounds.<sup>126</sup>

FT-IR spectroscopy provides information about identify unknown materials, determine the quality or consistency of a sample and determine the amount of components in a mixture. An infrared spectrum represents a fingerprint of a sample with absorption peaks which correspond to the frequencies of vibrations between the bonds of the atoms making up the material. Because each different material is a unique combination of atoms, no two compounds produce the exact same infrared spectrum. Therefore, infrared spectroscopy can result in a positive identification (qualitative analysis) of every different kind of material.

The IR spectra of samples were taken in the range between 4000–400 cm<sup>-1</sup> in KBr pellets. IR spectrums of some of the synthesized samples with different metal salts are depicted in fig. 3.4. The IR spectrum of the samples shows that a band in the region from 1661-1681 cm<sup>-1</sup> is due to C=N stretching. Similarly a band in the region between 405-470 cm<sup>-1</sup> is attributed to the Cu-N stretching. The other bands in the

<sup>126</sup> Jacox, Marilyn E. (2003). "Vibrational and Electronic Energy Levels of Polyatomic Transient Molecules. Supplement B". *Journal of Physical and Chemical Reference Data* **32** (1): 1. doi :10.1063/1.1497629. ISSN 0047-2689

George Socrates (12 April 2004). *Infrared and Raman Characteristic Group Frequencies: Tables and Charts*. John Wiley & Sons. pp. 18-. ISBN 978-0-470-09307-8. Retrieved 5 December 2012.

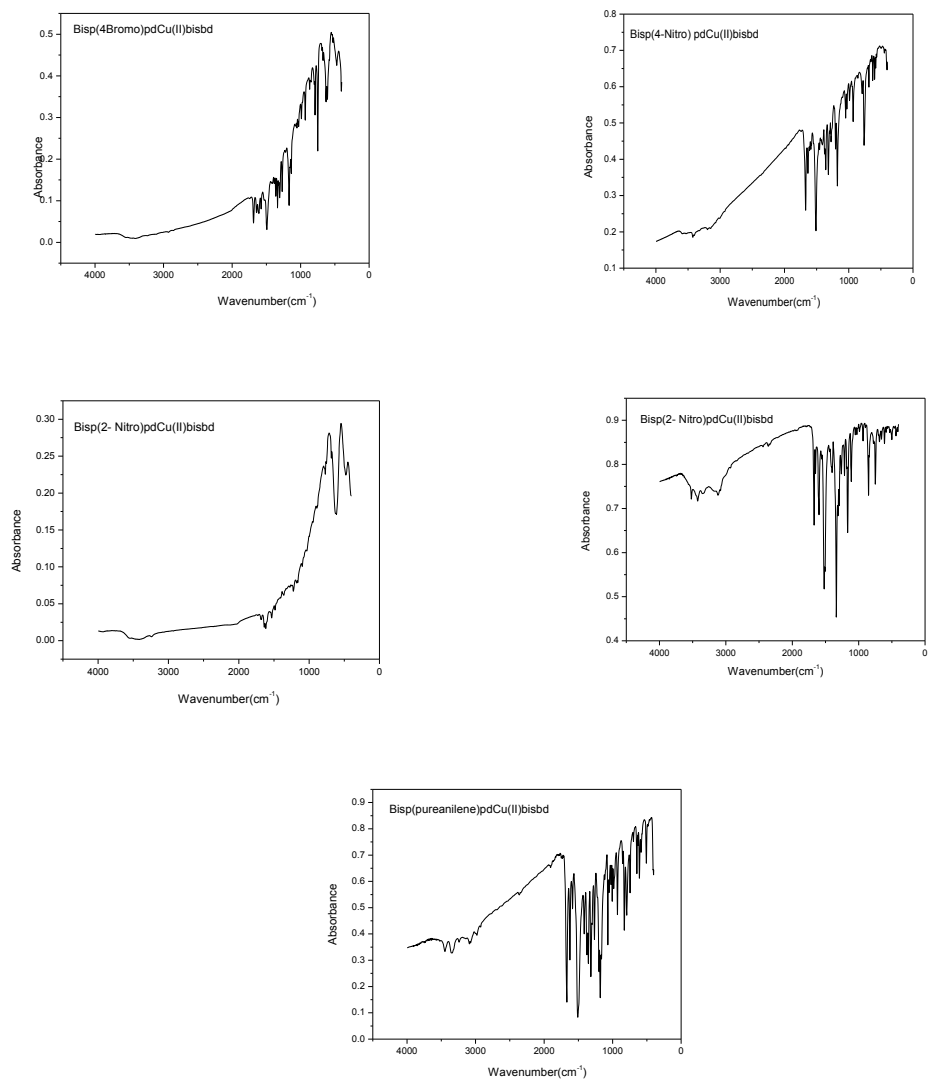
region between 830-850  $\text{cm}^{-1}$ , is for para substituted benzene, 745-775  $\text{cm}^{-1}$  is for ortho substituted benzene and 690-700  $\text{cm}^{-1}$  is for mono substituted benzene. Further confirm the samples structure. Moreover, a detailed view of data is given in Table.3.5<sup>127</sup>.

<b>Table 3.5 FT-IR Spectral data of copper complexes</b>		
<b>S. No.</b>	<b>Complex Name</b>	<b>IR</b>
1	<b>Bisp(4Bromo)pdCu(II)bisbd</b>	<b>1671.25 (C=N)</b>
		<b>405.81 (Cu-N)</b>
		<b>831.63 (Para Substituted Benzene)</b>
2	<b>Bisp(4-Nitro) pdCu(II)bisbd</b>	<b>1681.25 (C=N)</b>
		<b>433.80 (Cu-N)</b>
		<b>849.62 (Para Substituted Benzene)</b>
3	<b>Bisp(2- Nitro)pdCu(II)bisbd</b>	<b>1691.24 (C=N)</b>
		<b>405.81 (Cu-N)</b>
		<b>745.66 (Ortho Substituted Benzene)</b>
4	<b>Bisp(2chloro)pdCu(II)bisbd</b>	<b>1671.25 (C=N)</b>
		<b>405.81 (Cu-N)</b>
		<b>755.66 (Ortho Substituted Benzene)</b>
5	<b>Bisp(pure anilene)pdCu(II)bisbd</b>	<b>1663.26 (C=N)</b>
		<b>471.78 (Cu-N)</b>
		<b>697.66 (Mono Substituted Benzene)</b>

<sup>127</sup> Kazuo Nakamoto (16 January 2009). *Infrared and Raman Spectra of Inorganic and Coordination Compounds, Applications in Coordination, Organometallic, and Bioinorganic Chemistry*. John Wiley & Sons. pp. 9-. ISBN 978-0-470-40587-1. Retrieved 13 December 2012.

Peter Larkin (25 May 2011). *Infrared and Raman Spectroscopy: Principles and Spectral Interpretation*. Elsevier. ISBN 978-0-12-386984-5. Retrieved 5 December 2012.

FTIR spectroscopy: principal, technique and mathematics, Int. J. Pharma and Bio Sciences, (2011), 2(1).



**Figure 3-4 IR spectra of copper complexes.**



### **3.6 Conclusion**

On the basis of the above spectroscopic characterization and studies, it is suggested that the structure for the copper metal complexes and copper salts are in the consistent with the desired structure.

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