SYNTHESIS, CHARACTERIZATION
AND BIOLOGICAL ACTIVITIES OF
BENZENESULFANOHYDRAZONES
AND THEIR METAL COMPLEXES

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Abstract

The Schiff bases of 2-hydroxyacetophenone benzenesulfanohydrazones and their metal complexes with Zn(II), Ni(II) and Cu(II) were synthesized. All the ligands and complexes were characterized by IR, NMR, UV spectroscopy, TGA and x-ray crystallographic techniques. From the spectroscopic and x-ray crystallographic studies showed that the ligand 2-hydroxyacetophenone benzenesulfanohydrazones form metal complexes with N, O-coordination. All the ligands and their metal complexes were tested for anti-ulcerogenic activity on Sprague-Dawley rats. The Schiff bases of 2-hydroxyacetophenone benzenesulfonohydrazone excellently inhibited gastric lesions on the glandular part of the stomach. It is believed that ulcer inhibition did not influence by the production of mucus and gastric juice acidity. The hemorrhagic lesions were found to be prevented even though the mucus secreted is lower than that secreted by the positive control (Cimetidine). This could explain that other mechanisms may take place during the prevention. The biological activities were ran at Molecular Medicine Department, Faculty of Medicine, University of Malaya.
Acknowledgment

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I dedicate this thesis to my husband Mohammed and my daughters, Noor El-Huda and Raghad.
# List of Figures

<table>
<thead>
<tr>
<th>Figure</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fig.1.1: General structure of Schiff base</td>
<td>1</td>
</tr>
<tr>
<td>Fig.1.2: Structure of Cimetidine</td>
<td>4</td>
</tr>
<tr>
<td>Fig.1.3: Structure of benzenesulfanohydrazine with salicylaldehyde</td>
<td>7</td>
</tr>
<tr>
<td>Fig.1.4: General structure of the metal complexes</td>
<td>8</td>
</tr>
<tr>
<td>Fig.1.5: General reaction to prepare ligands</td>
<td>9</td>
</tr>
<tr>
<td>Fig.1.6: General reaction to synthesize metal complexes</td>
<td>10</td>
</tr>
<tr>
<td>Fig. 3.1: The $^1$H NMR spectrum of HapBsh</td>
<td>40</td>
</tr>
<tr>
<td>Fig.3.2: The $^{13}$C NMR spectrum of HapBsh</td>
<td>41</td>
</tr>
<tr>
<td>Fig.3.3: View of part of a hydrogen-bonded chain, H atoms shown as spheres of arbitrary radius. The dashed lines represent the intra- and intermolecular hydrogen bonds</td>
<td>42</td>
</tr>
<tr>
<td>Fig.3.4: The IR spectrum of Ni(HapBsh)$_2$</td>
<td>43</td>
</tr>
<tr>
<td>Fig. 3.5: The IR spectrum of Cd(HapBsh)$_2$</td>
<td>43</td>
</tr>
<tr>
<td>Fig.3.6: The IR spectrum of [Cu(HapBsh)]$_2$</td>
<td>44</td>
</tr>
<tr>
<td>Fig.3.7: The $^{13}$C NMR spectrum of Ni(HapBsh)$_2$</td>
<td>45</td>
</tr>
<tr>
<td>Fig.3.8: The TGA spectrum of Cd(HapBsh)$_2$</td>
<td>48</td>
</tr>
<tr>
<td>Fig.3.9: The TGA spectrum of [Cu(HapBsh)]$_2$</td>
<td>49</td>
</tr>
<tr>
<td>Fig.3.10: The TGA spectrum of Ni(HapBsh)$_2$</td>
<td>50</td>
</tr>
<tr>
<td>Fig.3.11: The IR spectrum of ClHapBsh</td>
<td>53</td>
</tr>
<tr>
<td>Fig.3.12: The $^{13}$C NMR spectrum of ClHapBsh</td>
<td>55</td>
</tr>
<tr>
<td>Fig.3.13: View of the hydrogen-bonded structure of ligand (3.1.2). H atoms are shown as spheres of arbitrary radius. The dashed lines represent intra- and intermolecular hydrogen bonds</td>
<td>56</td>
</tr>
<tr>
<td>Fig.3.14: The IR spectrum of [Ni(ClHapBsh)]$_2$</td>
<td>56</td>
</tr>
<tr>
<td>Fig.3.15: The IR spectrum of [Cu(ClHapBsh)]$_2$</td>
<td>57</td>
</tr>
<tr>
<td>Fig.3.16: The $^{13}$C NMR spectrum of [Cu(ClHapBsh)]$_2$</td>
<td>58</td>
</tr>
<tr>
<td>Fig.3.17: The TGA spectrum of [Cu(ClHapBsh)]$_2$</td>
<td>60</td>
</tr>
<tr>
<td>Fig.3.18: The TGA spectrum of [Ni(ClHapBsh)]$_2$</td>
<td>61</td>
</tr>
</tbody>
</table>
List of Figures (Continued):

Fig.3.19: The IR spectrum of FHapBsh 65
Fig.3.20: The IR spectrum of Zn(FhapBsh)₂ 67
Fig.3.21: The IR spectrum of [Cu(FhapBsh)]₂ 68
Fig.3.22: The IR spectrum of [Ni(FhapBsh)]₂ 68
Fig.3.23: The IR spectrum of Cd(FhapBsh)₂H₂O 69
Fig.3.24: The ¹³C NMR spectrum of Cd(FhapBsh)₂H₂O 70
Fig.3.25: The ¹³C NMR spectrum of [Ni(FhapBsh)]₂ 70
Fig.3.26: The TGA spectrum of [Cd(FhapBsh)]₂H₂O 73
Fig.3.27: The TGA spectrum of [Ni(FhapBsh)]₂ 74
Fig.3.28: The IR spectrum of BrHapBsh 79
Fig.3.29: The structure of the two independent molecules of (3.1.4). H atoms are shown as spheres of arbitrary radius. Intramolecular hydrogen bonds are shown dashed 81
Fig.3.30: The IR spectrum of [Ni(BrHapBsh)]₂ 82
Fig.3.31: The IR spectrum of [Cu(BrHapBsh)]₂(DMSO)₂ 83
Fig.3.32: The IR spectrum of Cd(BrHapBsh)₂ 84
Fig.3.33: The IR spectrum of [Zn(BrHapBsh)]₂H₂O 84
Fig.3.34: The ¹H NMR spectrum of [Ni(BrHapBsh)]₂ 85
Fig.3.35: The ¹³C NMR spectrum of [Ni(BrHapBsh)]₂ 86
Fig.3.36: The structure of the symmetric dinuclear Cu(II) complex of [BrHapBsh] 87
Fig.3.37: The TGA spectrum of Cd(BrHapBsh)₂ 89
Fig.3.38: The TGA spectrum of [Ni(BrHapBsh)]₂ 90
Fig.3.39: The TGA spectrum of [Zn(BrHapBsh)]₂H₂O 91
Fig.3.40: The IR spectrum of methHapBsh 97
Fig.3.41: The ¹H NMR spectrum of methHapBsh 98
Fig.3.42: The ¹³C NMR spectrum of methHapBsh 100
Fig.3.43: The structure of the asymmetric unit of methHapBsh. 101
Fig.3.44: The IR spectrum of Cd(methHapBsh)₂ 102
List of Figures (Continued):

Fig.3.45: The IR spectrum of \([\text{Cu}(\text{methHapBsh})]_2\)  
Fig.3.46: The IR spectrum of \([\text{Ni}(\text{methHapBsh})]_2(\text{H}_2\text{O})_2\)  
Fig.3.47: The IR spectrum of \([\text{Zn}(\text{methHapBsh})]_2\text{H}_2\text{O}\)  
Fig.3.48: The $^1\text{H}$ NMR spectrum of \([\text{Cd}(\text{methHapBsh})]_2\)  
Fig.3.49: The $^1\text{H}$ NMR spectrum of \([\text{Ni}(\text{methHapBsh})]_2(\text{H}_2\text{O})_2\)  
Fig.3.50: The $^{13}\text{C}$ NMR spectrum of \([\text{Cd}(\text{methHapBsh})]_2\)  
Fig.3.51: The $^{13}\text{C}$ NMR spectrum of \([\text{Ni}(\text{methHapBsh})]_2(\text{H}_2\text{O})_2\)  
Fig.3.52: The $^{13}\text{C}$ NMR spectrum of \([\text{Zn}(\text{methHapBsh})]_2\text{H}_2\text{O}\)  
Fig.3.53: The TGA spectrum of \([\text{Cd}(\text{methHapBsh})]_2\)  
Fig.3.54: The TGA spectrum of \([\text{Cd}(\text{methHapBsh})]_2\)  
Fig.3.55: The TGA spectrum of \([\text{Ni}(\text{methHapBsh})]_2(\text{H}_2\text{O})_2\)  
Fig.3.56: The TGA spectrum of \([\text{Zn}(\text{methHapBsh})]_2\text{H}_2\text{O}\)  
Fig.4.1: View of outside the stomach (a) treated 95-100% inhibition (b) negative control group (tween 20)  
Fig.4.2: The open stomach (a) treated 95-100% inhibition (b) negative control group  
Fig.4.3: Histology study (a) negative control group with more damage in surface epithelium (b) treated animal stomach with less damage  
Fig.4.4: Prevention effect of benzenesulfanohydrazones (low dose) on mucus weight of rats stomach.  
Fig.4.5: Prevention effect of benzenesulfanohydrazones (low dose) on acidity of the gastric juice of pyloric ligated rats  
Fig.4.6: Prevention effect of benzenesulfanohydrazones (low dose) against ethanol induced ulcer. Columns represent the inhibition percentage of different ligands and its metal complexes
# List of tables

<table>
<thead>
<tr>
<th>Table</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table 3.1: Elemental analytical results of the HapBsh and its Cd(II), Cu(II) and Ni(II) complexes</td>
<td>38</td>
</tr>
<tr>
<td>Table 3.2: IR- spectra of HapBsh and its Cd(II), Cu(II) and Ni(II) complexes</td>
<td>38</td>
</tr>
<tr>
<td>Table 3.3: $^1$H NMR data of HapBsh and its Cd(II) and Ni(II) complexes</td>
<td>39</td>
</tr>
<tr>
<td>Table 3.4: $^{13}$C NMR data of HapBsh and its Cd(II) and Ni(II) complexes</td>
<td>40</td>
</tr>
<tr>
<td>Table 3.5: Electronic absorption spectra of HapBsh and its Cd(II), Cu(II) and Ni(II) complexes in the UV region</td>
<td>46</td>
</tr>
<tr>
<td>Table 3.6: TGA data of the Cd(HapBsh)$_2$, [Cu(HapBsh)]$_2$ and Ni(HapBsh)$_2$</td>
<td>47</td>
</tr>
<tr>
<td>Table 3.7: Elemental analytical results of the ligand ClHapBsh and Cu(II) and Ni(II) complexes</td>
<td>52</td>
</tr>
<tr>
<td>Table 3.8: IR- spectra of ClHapBsh and its Cd(II), Cu(II) and Ni(II) complexes</td>
<td>52</td>
</tr>
<tr>
<td>Table 3.9: $^1$H NMR data of ClHapBsh and its Cu(II) complex</td>
<td>53</td>
</tr>
<tr>
<td>Table 3.10: $^{13}$C NMR data of ClHapBsh and its Cu(II) complex</td>
<td>54</td>
</tr>
<tr>
<td>Table 3.11: Electronic absorption spectra of ClHapBsh and their metal complexes in the UV region</td>
<td>59</td>
</tr>
<tr>
<td>Table 3.12: TGA data of the [Cu(ClHapBsh)]$_2$ and [Ni(ClHapBsh)]$_2$</td>
<td>62</td>
</tr>
<tr>
<td>Table 3.13: Elemental analytical results of the ligand FHapBsh and its Cd(II), Cu(II), Ni(II) and Zn(II) complexes</td>
<td>63</td>
</tr>
<tr>
<td>Table 3.14: IR- spectra of FHapBsh and its Cd(II), Cu(II) and Ni(II) complexes</td>
<td>64</td>
</tr>
<tr>
<td>Table 3.15: $^1$H NMR data of FHapBsh and its Cd(II) and Ni(II) complexes</td>
<td>65</td>
</tr>
<tr>
<td>Table 3.16: $^{13}$C NMR data of FHapBsh and its Cu(II) and Ni(II) complexes</td>
<td>66</td>
</tr>
</tbody>
</table>
List of Tables (Continued):

Table 3.17: Electronic absorption spectra of FHapBsh and their metal complexes in the UV region

Table 3.18: TGA data of the [Cd(FHapBsh)]_2H_2O and [Ni(FHapBsh)]_2

Table 3.19: Elemental analytical results of the ligand BrHapBsh and its Cd(II), Cu(II), Ni(II) and Zn(II) complexes

Table 3.20: IR- spectra of BrHapBsh and its Cd(II), Cu(II), Zn(II) and Ni(II) complexes

Table 3.21: ¹H NMR data of BrHapBsh and its Ni(II) complex

Table 3.22: ¹³C NMR data of BrHapBsh and its Cd(II) and Ni(II) complexes

Table 3.23: Electronic absorption spectra of BrHapBsh and their metal complexes in the UV region

Table 3.24: TGA data of the Cd (BrHapBsh)_2, [Zn(BrHapBsh)]_2H_2O and [Ni(BrHapBsh)]_2

Table 3.25: Elemental analytical results of the ligand methHapBsh and its Cd(II), Cu(II), Ni(II) and Zn(II) complexes

Table 3.26: IR- spectra of methHapBsh and its Cd(II), Cu(II), Zn(II) and Ni(II) complexes

Table 3.27: ¹H NMR data of methHapBsh and its Cd(II), Cu(II), Ni(II) and Zn(II) complexes

Table 3.28: ¹³C NMR data of methHapBsh and its Cd(II), Cu(II), Ni(II) and Zn(II) complexes

Table 3.29: Electronic absorption spectra of methHapBsh and their metal complexes in the UV region

Table 3.30: TGA data of the Cd(methHapBsh)_2, [Cu(methHapBsh)]_2, [Ni(methHapBsh)]_2 and [Zn(methHapBsh)]_2H_2O

Table 4.1: Effect of Benzenesulfanohydrazone compounds(low dose) on gastric lesions and gastric secretion in rats

Table 4.2: Effect of Benzenesulfanohydrazone compounds(high dose) on gastric lesions and gastric secretion in rats
# List of Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>IR</td>
<td>Infrared Spectroscopy</td>
</tr>
<tr>
<td>ν</td>
<td>Frequency</td>
</tr>
<tr>
<td>KBr</td>
<td>Potassium Bromide</td>
</tr>
<tr>
<td>NMR</td>
<td>Nuclear Magnetic Resonance Spectroscopy</td>
</tr>
<tr>
<td>¹H NMR</td>
<td>Proton NMR</td>
</tr>
<tr>
<td>¹³C{¹H}NMR</td>
<td>Carbon 13 NMR</td>
</tr>
<tr>
<td>δ</td>
<td>Chemical shift</td>
</tr>
<tr>
<td>ppm</td>
<td>Part Per Million</td>
</tr>
<tr>
<td>s (NMR data)</td>
<td>Singlet peak</td>
</tr>
<tr>
<td>m (NMR data)</td>
<td>Multiplets peaks</td>
</tr>
<tr>
<td>UV</td>
<td>Ultraviolet Spectroscopy</td>
</tr>
<tr>
<td>TGA</td>
<td>Thermogravimetry Analysis</td>
</tr>
<tr>
<td>Ph-</td>
<td>Phenol</td>
</tr>
<tr>
<td>Ar-</td>
<td>Aromatic ring</td>
</tr>
<tr>
<td>DMSO</td>
<td>Dimethylsulfoxide</td>
</tr>
<tr>
<td>TMS</td>
<td>Tetramethylsilane</td>
</tr>
<tr>
<td>m.pt</td>
<td>Melting Point</td>
</tr>
<tr>
<td>ORTEP</td>
<td>Oak Ridge Thermal Ellipsoid Program</td>
</tr>
<tr>
<td>CONTENTS</td>
<td>PAGES</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>-------</td>
</tr>
<tr>
<td>Abstract</td>
<td>i</td>
</tr>
<tr>
<td>Abstrak</td>
<td>ii</td>
</tr>
<tr>
<td>Acknowledgement</td>
<td>iii</td>
</tr>
<tr>
<td>List of Figures</td>
<td>iv</td>
</tr>
<tr>
<td>List of tables</td>
<td>vii</td>
</tr>
<tr>
<td>List of Abbreviations</td>
<td>ix</td>
</tr>
</tbody>
</table>

**CHAPTER ONE:**

1.1. General Introduction on Schiff base 1

- Factors in the development of peptic ulcers 3

- Interactions of Cimetidine 4

- Important adverse effects of cimetidine 4

- Physical Chemistry of Alcohols 5

1.2. Literature review 6

1.3. The present work 8

1.4. Objectives of the present study 10

**CHAPTER TWO:**

Experimental methods of benezenesulfanohydrazone ligands and their metal complexes:

- 2.1. The chemical studies 12-32

- 2.2. The biological activities 33-37

**CHAPTER THREE:**

3.1. Characterization of benezenesulfanohydrazone ligands and their metal complexes 38-116

**CHAPTER FOUR:**

4.1. Discussion of the biological activities of benezenesulfanohydrazone ligands and their metal complexes 117-126
Conclusion 127-128

Contents (Continued):

References 129-133

List of Published papers and Conferences 134
Chapter 1

Introduction
1.1. General Introduction on Schiff base:

A Schiff base (or azomethine), is named after its inventor, Hugo Schiff and it is a functional group that contains a carbon-nitrogen double bond with the nitrogen atom connected to an aryl or alkyl group—but not hydrogen. Schiff bases have the general formula of $R_1R_2C=\text{N}-R_3$, where $R_3$ is an aryl or alkyl group that makes the Schiff base a stable imine. Schiff bases can be synthesized from a reaction of an aromatic amine and a carbonyl compound by a nucleophilic addition forming a hemiaminal, followed by a dehydration to generate an imine. ([International Union of Pure and Applied Chemistry].)

![Figure 1.1: General structure of Schiff base](image)

Schiff base ligands are able to coordinate to many different metals ([Khalil et al., 2000], and stabilized in various oxidation states. The Schiff bases complexes have been used in catalytic reactions ([Hamilton et al., 1987], and as models for biological systems ([Chen et al., 1987]). It has been reported that the structure of the substituent bonded to the imino nitrogen affects the coordination geometry of the complex ([Yildirm et al., 2002]). They are described by ([M. Zarei Molbank et al., 2004]) as any of a class of derivatives of the condensation of aldehydes or ketones with primary amines. They are colorless crystals, weakly basic compounds and can be hydrolyzed by water and strong acids to form carbonyl compounds and amines. Most of the Schiff bases are used as chemical intermediates, perfume bases, dyes, rubber accelerators and in liquid crystals for electronics. Schiff bases were discovered by Hugo (Ugo) Schiff (26 April 1834 – 8 September 1915). He was a German chemist, born in Frankfurt. In 1879 he
discovered Schiff bases and other imines, and was responsible for research in aldehydes and had the Schiff test named after him (*International Union of Pure and Applied Chemistry*). During the past two decades, considerable attention has been paid to the chemistry of the metal complexes of Schiff bases containing nitrogen and other donors (*Djebber et al., 1997*). This may be attributed to their stability and biological activities (*Liu et al., 1996*). It is well known that some drugs have higher activity when administered as metal complexes than free ligands (*Ramesh et al. 2003*). For example Cu(II) complex of salicylaldehyde benzoylehydrazone was shown to be a potent inhibitor of DNA synthesis and cell growth (*Chand et al., 1995*). There are also some reports on the antimicrobial activities by using benzenesulfanohydrazones and their complexes (*Tawfik et al., 1989*). Previous work on synthesis and characterization of Schiff bases ligands and their complexes had indicated the biological activity of these compounds against oxidation, higher than vitamin E (*Hapipah et al., 2006*), antibacterial activity (*Hapipah et al., 2006*), antiproliferative and antiviral activities (*Paola et al., 2003*). So we wish to extend this work by using different compounds and different biological activities. There are very few studies that have been reported on Schiff bases of benzosulfanohydrazones and their biological activity especially as an anti-ulcerogenic agent. A brief introduction on the stomach ulcer and its treatment are given follows.

The ulcer is an open sore, or lesions, usually found on the skin or mucous membrane areas of the body. A peptic ulcer is a lesion occurs at the lining of the stomach or duodenum, where hydrochloric acid and pepsin are present. In the past, it was believed that lifestyle factors, such as stress and diet can cause ulcers. Later, researchers have determined that stomach acids – hydrochloric acid and pepsin – contributed to ulcer formation.

Today, research shows that most ulcers (80 % of gastric ulcers and 90 % of duodenal ulcers) can develop as a result of information with a bacterium called Helicobacter pylori (H. pylori).
It is believed that, although all the three factors – lifestyle, acid and pepsin, and H. pylori – play a role in ulcer development, H. pylori is considered to be the primary cause.

Factors in the development of peptic ulcers

- helicobacter pylori
- smoking
- caffeine
- alcohol
- stress
- acid and pepsin
- non-steroidal anti-inflammatory drugs (NSAIDs)

People with ulcers may experience serious complication if they do not get treatment. The most common problems include:

- bleeding
- perforation
- narrowing and obstruction of the intestinal opening, resulting in vomiting.

(University of Maryland Medical Center, 2006)

Many of the past successes in medicinal chemistry have involved the fortuitous discovery of useful pharmaceutical agents from natural sources such as plants or microorganisms. Analogues of these structures were then made in an effort to improve activity and/ or to reduce side-effects, but often these variations were carried out on a trial-and-error basis. While this approach yielded a large range of medicinal compounds, it was wasteful with respect to the time and effort involved. In the last twenty to thirty years, greater emphasis has been placed on rational drug design whereby drugs are designed to interact with a known biological system. One of the early examples of the rational approach to drug design was the
development of the anti-ulcer drug Cimetidine (Fig. 1.2), carried out by scientists at Smith, Kline, & French (SK&F) (Patrick, 2001).

![Structure of Cimetidine](image)

**Figure 1.2:** Structure of Cimetidine

**Interactions of Cimetidine:**

There are two mechanisms whereby Cimetidine interacts with other drugs:

- Inhibition of hepatic drug-metabolizing enzymes.
- Reduction in liver blood flow. By reducing liver blood flow, Cimetidine can reduce the clearance of drugs with a high extraction ratio.

**Important adverse effects of cimetidine:**

- Cimetidine causes an increase in plasma prolactin concentrations.
- These drugs might cause gastric carcinoma (Smith et al. 2002)

Where the Cimetidine programme started in 1964, the methods available for treating peptic ulcers were few and generally unsatisfactory. Ulcers are localized erosions of the mucous membranes of the stomach or duodenum. It is not known how these ulcers arise, but the presence of gastric acid aggravates the problem and delays recovery. Ulcer sufferers often suffer intense pain for many years, and if left untreated, the ulcer could result in severe bleeding and even death. In the early 1960s, the conventional treatment was to try neutralize gastric acid in the stomach by administering bases such as sodium bicarbonate or calcium carbonate. However, the dose levels required for neutralization were large and caused unpleasant side-effects. Relief was also only temporary and patients were often advised to stick to rigid diets such as strained porridge and steamed fish. Ultimately, the only answer
was surgery to remove part of the stomach. It was reasoned that a better approach would be to inhibit the release of gastric acid at source (Graham L. Patrick, 2001).

**Physical Chemistry of Alcohols**

Alcohol comes under **group1 carcinogens** as classified by World Health Organization (WHO). Although, previous studies have failed to establish direct connection between alcohol and its effect on cancer, there is strong indication to suggest that alcohol can enhance the effects of other carcinogenic chemicals like tobacco. Acetaldehyde, the byproduct of metabolism of alcohol, if gets concentrated in high amounts then it can damage the DNA of cells. Their reaction with polyamines can end up in forming mutagenic DNA. The excessive consumption of ethanol also makes mouth, larynx, pharynx, esophagus more prone to cancer. Alcohol can be absorbed from the stomach or by inhalation in the lungs, distributed throughout the body fluids and tissues via the blood, eliminated only slowly via the lungs, kidneys and skin, and removed chiefly by slow metabolic oxidation. It is generally agreed that alcohols are transferred across biological membranes by simple diffusion. Essentially, the primary alcohols consist of an –OH group linked to hydrocarbon chains increasing in length from two atom in ethanol. The terminal –OH group, having a $K_a$ of $7.3 \times 10^{-20}$, is very similar to the –OH of the water. Lower alcohols are moderately polar as indicated by their dielectric constant and dipole moments. They form hydrogen bonds readily, so that they exhibit intermolecular association in the same way as water. Both alcohols and water show an unusually high rate of hydrogen ion conductance in an electric field, as a result of successive chain like transfer of protons from one alcohol molecule to another. The properties of the alcohol molecule represent a balance of the respective contributions of the –OH and hydrocarbon portions. Thus, in ethanol contributions of the –OH group predominates, and the ethanol is infinitely soluble. So alcohol molecules associate preferentially with other alcohol, hydrocarbon, or lipid molecules, rather than in water. This is reflected in a progressive
decrease in water solubility and an increase in oil-water partition coefficients. There is no doubt that ethanol and other alcohols can be absorbed through the mucosa of whole gastrointestinal tract, from the mouth to rectum. The maximum absorption of alcohol is across the mucosa of the stomach and the minimum will be from the mouth. In rats in which the pylorus had been ligated, the gastric absorption of ethanol is 40\% of a test dose in 20 minutes and up to 60\% in an hour (Benjamine et al., 1971).

1.2. Literature review:

Benzenesulfanohydrazones was first characterized by Tawfik et al (1989). Salicylidinebenzenesulfonylhydrazone (HSBS) and its Co(II), Ni(II), Co(II) and Zn(II) complexes were synthesized and characterized by elemental analyses, molar conductivities, magnetic moments, IR, NMR and TGA measurements. All the results confirmed the monomeric nature for Ni(II) and Co(II) complexes. HSBS also coordinated in a monodentate fashion via an NH group with displacement of a proton by the metal atom. The participation of the SO$_2$ moiety in bridging the polymeric chains was proposed for all complexes having the general formula \([M(SBS)_2]_n \) \(M=\text{Co(II), Zn(II) or Cd(II)}\). These results agreed with (Rakha et al., 1987) study. But these structures were not confirmed by x-ray structure and are still proposed structure. (Tawfik et al., 1989) had also studied the antimicrobial activity in vitro biogram which was conducted by Harper and Cowston method (Horper et al., 1945). The antimicrobial activity data for HSBS and its metal complexes clearly showed that the Cu(II) and Ni(II) complexes had similar antimicrobial activity against gram-positive bacterium (B. subtilis) and gram-negative bacterium (E. coli). These two complexes were also effective against the fungus A. alternata. On the other hand, according to (Jain et al., 1979) HSBS as well as Co(II) and Zn(II) complexes did not show any appreciable antimicrobial activity.
In 1959, Zimmer et al. had studied about behavior of four substituted benzenesulfanohydrazones against Streptococcus, Micrococcus pyogenes and Escherichia coli bacteria. He found that the compounds were active against these bacteria. In 1992 Ahmed Shawalli et al. had studied six ligands of benzenesulfanohydrazones and their Cu(II) and Ni(II) complexes. The reactivity and their acid-base properties were studied. It was found that the distinguishing structural feature of the hydrazone group was the presence of two (imino and amino) nitrogen atoms with their valency electrons which differ in their hybridization. In that study, the possibility of chelate formation via hydrogen bond between the nitrogen atom of the benzenesulfanohydrazones and the hydrogen atom of salicylaldehyde, were reported (Figure 1.3).

![Structure of benzenesulfanohydrazine with salicylaldehyde](image)

**Figure 1.3:** Structure of benzenesulfanohydrazine with salicylaldehyde

This proposed structure agreed with the x-ray structure of benzenesulfanohydrazones studied by Hussain et al., 1995, which discussed the same structure according to x-ray structure. The hydrogen bond was described in the present work of the ligands of benzenesulfanohydrazine with hydroxyacetophenone and its chloro and bromo substituents. Both Ahmed Shawalli (1992) and Hussain (1995) had proposed the same structure for the metal complexes as shown in Figure 1.4.
Figure 1.4: General structure of the metal complexes

There are no biological studies on benzenesulfanohydrazones that had been investigated other than antimicrobial, antibacterial and antifungal. Other biological studies such as anti stomach ulcer, in vivo toxicity should be investigated on these unique groups of the compounds. Moreover all that studies were run on vitro (cells). So it is very important to continue the study of these unique group of the compounds. Because of that I prefer to use different field of study focus on anti stomach ulcer and test its toxicity, all by using rats (vivo model).

1.3- The present work:

This study is divided into three stages. In the first stage, the ligands were prepared from benzenesulfanohydrazine and hydroxyacetophenone (Figure1.5). The second stage will be synthesis of Zn(II), Cu(II), Ni(II) and Cd(II) complexes (Figure1.6). All the ligands and complexes will be characterized by using IR, NMR, TGA, elemental analysis and x-ray diffraction measurements. In the final stage, the acute toxicity and anti-ulcerogenic activity of the ligands and the metal complexes will be investigated.
Figure 1.5: General reaction to prepare ligands
1.4. Objectives of the present study:

- To synthesize and analyze the structures of benzenesulfanohydrazones ligands by spectroscopic data such as IR, \(^1\)H & \(^{13}\)C NMR, UV-visible, thermogravimetry, x-ray diffraction and elemental analysis

- To synthesize and analyze the structures of benzenesulfanohydrazones Cd(II), Cu(II), Ni(II) and Zn(II) complexes by spectroscopic data such as IR, \(^1\)H & \(^{13}\)C NMR, UV-visible, thermogravimetry, x-ray diffraction and elemental analysis

Figure 1.6: General reaction to synthesize metal complexes
• To determine the biological properties: acute toxicity and anti-ulcer properties of benzenesulfanohydrazones and their metal complexes.
Chapter 2

Experimental Methods
2.1: **The chemical studies:**

All chemicals used in this study were obtained from Fluka and Aldrich used as received without further purification. Ligands and complexes were synthesized by direct reaction of the reactants. The two ethanolic solutions were stirred for 2 or 5 hours after it dissolved completely. Then the ethanol was evaporated by using Rota evaporator. Single crystals of the ligands were obtained by slow evaporation of their ethanolic solution in air. The crystals of the complexes were obtained by recrystallization in DMSO.

Infrared spectra were obtained using KBr discs (4000-400 cm⁻¹) on Perkin–Elmer FT-IR spectrometer. \(^1\)H and \(^{13}\)C NMR spectra were recorded on Jeol JNM-LA400 FT-NMR system. TMS was used as internal standard and deuteriated DMSO as solvent. The electronic spectra in the 200-800nm range were obtained in DMSO on a Cary 50Conc. UV-visible recording/spectrophotometer. The concentration of the samples 10⁻³-10⁻⁴M. Thermal analysis studies of the complexes were performed on Perkin-Elmer Pyris Diamond DTA/TG Thermal System under nitrogen atmosphere at a heating rate of 10°C/min. from 30-900°C. Elemental analysis (C, H, N) were performed by using a Flash EA 1112 Series elemental analyzer in University of Technology Malaysia. The x-ray diffraction measurements were obtained from University of Canterbury, New Zealand.
Preparation of ligands:

2’-[1-(2-Hydroxyphenyl)ethylidene]benzenesulfanohydrazide

[\text{HapBsh}]

\[
\begin{align*}
\text{H}_3\text{C} & \quad \text{N} \\
\text{N} & \quad \text{H} \\
\text{S} & \quad \text{H}_3\text{C} \\
\text{O} & \quad \text{O} \\
\text{OH} & 
\end{align*}
\]

Benzenesulfanohydrazide (0.690g, 0.004mol) was refluxed in acidified ethanol (50mL) with 2-hydroxyacetophenone (0.69g, 0.004mol) for 2 hours afforded pale yellow crystals. Yield = 75%, m.pt=140 °C.

Elemental Analysis:

Found: C(57.85%) ; H(4.90%) ; N(9.87%)

Theory: C(57.93%) ; H(4.86%) ; N(9.65%)

IR Spectra (KBr)

3444cm\(^{-1}\) (\(\nu\) Ar-OH), 3235cm\(^{-1}\) (\(\nu\) N-H), 1607cm\(^{-1}\) (\(\nu\) C=N), 1353cm\(^{-1}\) (\(\nu\) S=O), 1164cm\(^{-1}\) (\(\nu\) S=O), 1084cm\(^{-1}\) (\(\nu\) C=O), 1022cm\(^{-1}\) (\(\nu\) N-N)

\(^1\)H NMR (DMSO)

11.59ppm [\(\delta\)(OH), 1H, s], 11.07ppm [\(\delta\)(NH), 1H, s], 6.807-7.90 ppm [\(\delta\)(aromatic), m], 2.2ppm [\(\delta\)(-CH\(_3\)), 3H, s]

\(^13\)C \text{ (}^1\text{H}) \text{ NMR (DMSO)}

158.70ppm \(\delta\)(C=N) , 157.52ppm \(\delta\)(C-O) , 116.9-138.28ppm \(\delta\)(aromatic), 14.65ppm \(\delta\)(-CH\(_3\))
2’- (5-Chloro-2-hydroxybenzylidene)benzenesulfanohydrazide

[ClHapBsh]

Benzenesulfanohydrazide (0.690g, 0.0035 mol) was refluxed in acidified ethanol (50mL) with 5’-chloro-2’-hydroxyacetophenone (0.60g, 0.0035mol) for 2 hours afforded pale yellow crystals. Yield = 75%, m.pt=150 °C.

Elemental Analysis:

Found: C(51.83%) ; H(4.33%) ; N(8.50%)

Theory: C(51.72%) ; H(4.00%) ; N(8.62%)

IR Spectra (KBr)

3423cm⁻¹ (ν Ar-OH), 3232cm⁻¹ (ν N-H), 1603cm⁻¹ (ν C=N), 1324cm⁻¹ (ν S=O), 1158cm⁻¹ (ν S=O), 1074cm⁻¹ (ν C-O), 1020cm⁻¹ (ν N-N)

¹H NMR (DMSO)

11.43ppm [δ(OH),1H, s], 11.19ppm [δ(NH),1H,s], 6.836-7.88ppm [δ(aromatic), m], 2.07ppm [δ(-CH₃), 3H, s]

¹³C {¹H} NMR (DMSO)

157.09ppm δ(C=N), 156.12ppm δ(C-O), 118.7-138.45ppm δ(aromatic), 14.86ppm δ(-CH₃)
2’-(5-Flouro-2-hydroxybenzylidene) benzenesulfanohydrazide

\[ \text{[FHapBsh]} \]

![Chemical Structure](image)

A solution of Benzenesulfanohydrazide (0.690 g, 0.004 mol) in acidified ethanol (30 mL) was added over a solution of 5’-flouro-2’-hydroxyacetophenone (0.69 g, 0.004 mol) in the same solvent (30 mL). The mixture was refluxed in room temperature for 2 hours. The product precipitated as a yellow solid. Yield = 80%, m.pt=140 °C.

**Elemental Analysis:**

Found: C(54.56%) ; H(4.64%) ; N(9.37%)

Theory: C(54.48%) ; H(4.21%) ; N(9.08%)

**IR Spectra (KBr)**

3423 cm\(^{-1}\) (\(\nu\) Ar-OH), 3149 cm\(^{-1}\) (\(\nu\) N-H), 1573 cm\(^{-1}\) (\(\nu\) C=N), 1325 cm\(^{-1}\) (\(\nu\) S=O), 1161 cm\(^{-1}\) (\(\nu\) S=O), 1075 cm\(^{-1}\) (\(\nu\) C-O), 1021 cm\(^{-1}\) (\(\nu\) N-N)

**\(^1\)H NMR (DMSO)**

11.36 ppm [\(\delta\)(OH), 1H, s], 11.19 ppm [\(\delta\)(NH), 1H, s], 6.805-7.843 ppm [\(\delta\)(aromatic), m]

2.22 ppm [\(\delta\)(-CH\(_3\)), 3H, s]

**\(^{13}\)C \(^1\)H) NMR (DMSO)**

157.82 ppm \(\delta\)(C=N), 154.14 ppm \(\delta\)(C-O), 114.87-148.28 ppm \(\delta\)(aromatic), 15.310 ppm \(\delta\) (-CH\(_3\))
2’- (5-Bromo -2-hydroxybenzylidene) benzenesulfanohydrazide

[BrHapBsh]

Benzenesulfanohydrazide (0.690g, 0.0028 mol) was refluxed in acidified ethanol (50mL) with 5’-bromo -2’-hydroxyacetophenone (0.48g, 0.0028mol) for 2 hours afforded yellow crystals. Yield =80 %, m.pt=140 °C.

Elemental Analysis:

Found: C(45.81%) ; H(3.02%) ; N(7.53%)
Theory: C(45.49%) ; H(3.52%) ; N(7.58%)

IR Spectra (KBr)

3423cm⁻¹( ν Ar-OH), 3232cm⁻¹( ν N-H), 1609cm⁻¹( ν C=N), 1321cm⁻¹( ν S=O), 1158cm⁻¹( ν S=O), 1086cm⁻¹( ν C-O), 1019cm⁻¹( ν N-N)

¹H NMR (DMSO)

11.65ppm [δ(OH), 1H, s], 10.42ppm [δ(NH), 1H, s], 6.802-8.117ppm [δ(aromatic), m], 2.49ppm [δ(-CH₃), 3H, s]

¹³C {¹H} NMR (DMSO)

155.56ppm δ(C=N), 143.57ppm δ(C-O), 110.59-138.79ppm δ(aromatic), 13.00 ppm δ(-CH₃)
2’-(5-Methyl-2-hydroxybenzylidene) benzenesulfanohydrazide

[methHapBsh]

Benzenesulfanohydrazide (0.690g, 0.004mol) was refluxed in acidified ethanol (50mL) with 2’-hydroxy 5’-methyl-acetophenone (0.69g, 0.004mol) for 2 hours afforded yellow solid product. Yield =80 %, m.pt=130 °C.

Elemental Analysis:

Found: C(59.19%) ; H(5.60%) ; N(9.26%)

Theory: C(59.13%) ; H(5.25%) ; N(9.19%)

IR Spectra (KBr)

3382cm⁻¹(ν Ar-OH), 3242cm⁻¹(ν N-H), 1609cm⁻¹(ν C=N), 1323cm⁻¹(ν S=O), 1169cm⁻¹(ν S=O), 1083cm⁻¹(ν C-O), 1042cm⁻¹(ν N-N)

¹H NMR (DMSO)

11.35ppm [δ(OH), 1H, s] ,11.02ppm [δ(NH), 1H, s], 6.699-7.897ppm [δ(aromatic), m], 2.26ppm [δ(-CH₃), 3H, s] , 2.19ppm [δ(Ar -CH₃), 3H, s]

¹³C {¹H} NMR (DMSO)

158.81ppm δ(C=N) , 155.34ppm δ(C-O) ,116.75-138.316ppm δ(aromatic), 20.12ppm δ(-CH₃), 14.61ppm (δAr-CH₃)
Preparation of complexes:

Cd(HapBsh)$_2$

A solution of cadmium (II) acetate (0.14g, 0.00053mole) in basified ethanol (50ml) was added slowly to a solution of 2’-[1-(2-hydroxyphenyl) ethylidene]benzenesulfanohydrazide (0.30g, 0.0011mole) in the same solvent in 1:2 molar ratio. The mixture was stirred and refluxed for 5 hours. White solid product was formed. Yield = 60%, m.pt=150 °C.

Elemental Analysis:

Found: C(50.07%) ; H(3.20%) ; N(9.55%)

Theory: C(48.67%) ; H(3.77%) ; N(8.11%)

IR Spectra (KBr)

3235cm$^{-1}$ (ν N-H), 1600cm$^{-1}$ (ν C=N), 1299cm$^{-1}$ (ν S=O), 1164cm$^{-1}$ (ν S=O), 1085cm$^{-1}$ (ν C-O), 1035cm$^{-1}$ (ν N-N), 400 cm$^{-1}$ (ν M-N), 508 cm$^{-1}$ (ν M-O)

$^1$H NMR (DMSO)

12.19ppm [δ(NH), 1H, s], 6.74-7.82ppm [δ( aromatic), m], 2.21ppm [δ(-CH$_3$), 3H, s]

$^{13}$C {$^1$H} NMR (DMSO)

156.20ppm δ (C=N), 156.17ppm δ (C-O), 117-133ppm δ( aromatic), 14.49ppm δ(-CH$_3$)

[Cu(HapBsh)]$_2$
A solution of copper (II) acetate (0.114g, 0.00057mole) in basified ethanol (50ml) was added slowly to a solution of 2’-[1-(2-hydroxyphenyl) ethylidene]benzenesulfanohydrazide (0.33g, 0.0011mole) in the same solvent in 1:2 molar ratio. The mixture was stirred and refluxed for 5 hours. A green powder product was formed. Yield = 70%, m.pt=200 °C.

**Elemental Analysis:**

Found: C(45.37%) ; H(3.34%) ; N(6.41%)  
Theory: C(47.65%) ; H(3.68%) ; N(7.94%)

**IR Spectra (KBr)**

3442cm⁻¹ (ν H₂O), 1592cm⁻¹ (ν C=N), 1329cm⁻¹ (ν S=O), 1164cm⁻¹ (ν S=O), 1085cm⁻¹ (ν C-O), 1038cm⁻¹ (ν N-N), 442cm⁻¹ (ν M-N), 504 cm⁻¹ (ν M-O)

**Ni(HapBsh)₂**
A solution of nickel (II) acetate (0.15g, 0.0006 mole) in basified ethanol (50ml) was mixed with (50ml) of ethanolic solution of 2’-[1-(2-hydroxyphenyl) ethylidene]benzenesulfanohydrazide (0.35g, 0.0012 mole) in 1:2 molar ratio. The mixture was stirred and refluxed for 5 hours. Dark brown solid was formed. Yield = 65%, m.pt=160°C.

Elemental Analysis:

Found: C(51.36%) ; H(5.07%) ; N(7.25%)
Theory: C(52.77%) ; H(4.08%) ; N(8.79%)

IR Spectra (KBr)

3172 cm⁻¹(ν N-H), 1600 cm⁻¹(ν C=N), 1353 cm⁻¹(ν S=O), 1164 cm⁻¹(ν S=O), 1087 cm⁻¹(ν C=O), 1035 cm⁻¹(ν N=N), 441 cm⁻¹(ν M-N), 503 cm⁻¹(ν M-O)

¹H NMR (DMSO)

12.93 ppm [δ (N-H), 6.70-7.74 ppm [δ(aromatic), m], 2.16 ppm [δ(-CH₃), 3H, s]

¹³C {¹H} NMR (DMSO)

157.76 ppm δ (C=N), 116.33-131.35 ppm δ(aromatic), 13.13 ppm δ(-CH₃)

[Cu(ClHapBsh)]₂

A solution of copper (II) acetate (0.092g, 0.00046 mol) in (30ml) basified ethanol was mixed with (0.30g, 0.00092 mol) of 2’-(5-chloro-2-hydroxybenzylidene) benzenesulfanohydrazide
in 1:2 ratio. The mixture was refluxed for 5 hours, afforded green powder product. Yield = 75%, m.pt=210 °C.

**Elemental Analysis:**

Found: C(42.51%) ; H(4.04%) ; N(6.06%)

Theory: C(43.41%) ; H(3.10%) ; N(7.23%)

**IR Spectra (KBr)**

3232cm⁻¹ (ν N-H), 1579cm⁻¹ (ν C=N), 1322cm⁻¹ (ν S=O), 1158cm⁻¹ (ν S=O), 1099cm⁻¹ (ν C-O), 1036cm⁻¹ (ν N-N), 424cm⁻¹ (ν M-N), 517cm⁻¹ (ν M-O)

**¹H NMR (DMSO)**

11.63ppm [δ( NH), 1H, s], 6.8-7.8ppm [δ(aromatic), m], 2.2ppm [δ(-CH₃), 3H, s]

**¹³C {¹H} NMR (DMSO)**

158.74ppm δ(C=N) , 155.97ppm δ(C-O), 118-138ppm δ(aromatic), 14.64ppm δ(-CH₃)

[NI(ClHapBsh)]₂

A solution of nickel (II) acetate(0.12g, 0.00046 mol) in (30ml) basified ethanol was mixed with (0.30g, 0.00092mol) of 2'-(5-chloro-2-hydroxybenzylidene) benzenesulfanohydrazide
in 1:2 ratio. The mixture was refluxed for 5 hours, afforded brown product. Yield = 70%, m.pt=240 °C.

**Elemental Analysis:**

Found: C(42.22%) ; H(3.37%) ; N(7.50%)

Theory: C(43.96%) ; H(3.14%) ; N(7.32%)

**IR Spectra (KBr)**

3232cm⁻¹(ν N-H), 1541cm⁻¹(ν C=N), 1324cm⁻¹(ν S=O), 1158cm⁻¹(ν S=O), 1096cm⁻¹(ν C-O), 1039cm⁻¹(ν N-N), 497cm⁻¹(ν M-N), 578cm⁻¹(ν M-O)

\[\text{[Cd(FHapBsh)]}_2\text{H}_2\text{O}\]

A solution of cadmium(II) acetate (0.086g, 0.00032 mol) in basified ethanol (30mL) was added over a solution of 2’- (5-flouro -2-hydroxybenzylidene)benzenesulfanohydrazide (0.20g, 0.00065mol) in the same solvent (30mL). The mixture was refluxed in room temperature for 5 hours. The product precipitated as a yellow solid. Yield = 60%, m.pt=180 °C.

**Elemental Analysis:**

Found: C(40.21%) ; H(3.50%) ; N(5.01%)

Theory: C(39.30%) ; H(2.80%) ; N(6.55%)
IR Spectra (KBr)

1563cm⁻¹ (ν C=N), 1325cm⁻¹ (ν S=O), 1161cm⁻¹ (ν S=O), 1126cm⁻¹ (ν C-O), 1036cm⁻¹ (ν N-N), 403cm⁻¹ (ν M-N), 512cm⁻¹ (ν M-O)

¹³C {¹H} NMR (DMSO)

174.95ppm δ( C=N), 154.62ppm δ( C-O), 111.92-144.57ppm δ(aromatic), 21.28ppm δ(-CH₃)

[Ni(FHapBsh)]₂

A solution of copper(II) acetate (0.097g, 0.00049mol) in basified ethanol (30mL) was added over a solution of 2’-(5-flouro-2-hydroxybenzylidene) benzenesulfanohydrazide (0.30g, 0.00097mol) in the same solvent (30mL). The mixture was refluxed in room temperature for 5 hours. The product precipitated as a black solid. Yield = 70%, m.pt=160 °C.

Elemental Analysis:

Found: C(44.46%) ; H(3.94%) ; N(7.97%)

Theory: C(45.34%) ; H(3.24%) ; N(7.56%)

IR Spectra (KBr)

1539cm⁻¹ (ν C=N), 1322cm⁻¹ (ν S=O), 1163cm⁻¹ (ν S=O), 1077cm⁻¹ (ν C-O), 1040cm⁻¹ (ν N-N), 419cm⁻¹ (ν M-N), 509cm⁻¹ (ν M-O)

[Ni(FHapBsh)]₂
A solution of nickel(II) acetate (0.12g, 0.00049mol) in basified ethanol (30mL) was added over a solution of 2'- (5-flouro -2-hydroxybenzylidene) benzenesulfanohydrazide (0.30g, 0.00097mol) in the same solvent (30mL). The mixture was refluxed in room temperature for 5 hours. The product precipitated as a brown solid. Yield = 70%, m.pt=180 °C.

**Elemental Analysis:**

Found: C(44.51%) ; H(4.78%) ; N(5.86%)

Theory: C(46.06%) ; H(3.01%) ; N(7.67%)

**IR Spectra (KBr)**

1570cm\(^{-1}\) (ν C=N), 1325cm\(^{-1}\) (ν S=O), 1166cm\(^{-1}\) (ν S=O), 1074cm\(^{-1}\) (ν C-O), 1025cm\(^{-1}\) (ν N-N), 408cm\(^{-1}\) (ν M-N), 517cm\(^{-1}\) (ν M-O)

**\(^1\)H NMR (DMSO)**

6.51-7.72ppm [δ(aromatic), m], 2.0ppm [δ(-CH\(_3\)),3H,s]

**\(^{13}\)C {\(^1\)H} NMR (DMSO)**

154.24ppm δ(C=N), 144.23ppm δ(C-O), 125.42-132.13ppm δ(aromatic), 13.02ppm δ(-CH\(_3\))

Zn(FHapBsh)\(_2\)
A solution of zinc(II) acetate (0.11g, 0.00049mol) in basified ethanol (30mL) was added over a solution of 2’- (5-flouro -2-hydroxybenzylidene) benzenesulfanohydrazide (0.30g, 0.00097mol) in the same solvent (30mL). The mixture was refluxed in room temperature for 5 hours. The product precipitated as an yellow solid. Yield=50%, m.pt=180 °C.

**Elemental Analysis:**

Found: C(48.67%) ; H(4.27%) ; N(7.22%)

Theory: C(49.46%) ; H(3.53%) ; N(8.24%)

**IR Spectra (KBr)**

3150cm\(^{-1}\) (\(\nu\) N-H), 1560cm\(^{-1}\) (\(\nu\) C=N), 1325cm\(^{-1}\) (\(\nu\) S=O), 1162cm\(^{-1}\) (\(\nu\) S=O), 1076cm\(^{-1}\) (\(\nu\) C-O), 1047cm\(^{-1}\) (\(\nu\) N-N), 419cm\(^{-1}\) (\(\nu\) M-N), 525cm\(^{-1}\) (\(\nu\) M-O)

**\(^1\)H NMR (DMSO)**

11.68ppm [\(\delta\)(NH), 1H, s], 6.78-7.84ppm [\(\delta\)(aromatic), m], 2.2ppm [\(\delta\)(-CH\(_3\)), 3H, s]

**\(^{13}\)C \{\(^1\)H\} NMR (DMSO)**

156.51ppm \(\delta\)(C=N) , 154.26(C-O), 114.50-139.69ppm \(\delta\)(aromatic), 14.96ppm \(\delta\)(-CH\(_3\))

\(\text{Cd(BrHapBsh)}_2\)
Cadmium(II)acetate (0.072g, 0.00027 mol) was refluxed in basified ethanol (50mL) with 2’-(5-bromo -2-hydroxybenzylidene)benzenesulfanohydrazide (0.200g, 0.00054mol) for 5 hours afforded green solid as a product. Yield =65 %, m.pt=170 °C.

Elemental Analysis:

Found: C(39.76%) ; H(3.07%) ; N(5.01%)

Theory: C(39.71%) ; H(2.60%) ; N(6.62%)

IR Spectra (KBr)

3232cm⁻¹ (ν N-H), 1561cm⁻¹ (ν C=N), 1321cm⁻¹ (ν S=O), 1158cm⁻¹ (ν S=O), 1091cm⁻¹ (ν C-O), 1023cm⁻¹ (ν N-N), 420cm⁻¹ (ν M-N), 514cm⁻¹ (ν M-O)

¹³C {¹H} NMR (DMSO)

157.76ppm δ(C=N) , 145.83(C-O), 109.14-130.24ppm δ(aromatic), 12.27ppm δ(-CH₃)

[Cu(BrHapBsh)]₂(DMSO)₂
Copper(II) acetate (0.0811g, 0.00041 mol) was refluxed in basified ethanol (50mL) with 2’- (5-bromo -2-hydroxybenzylidene)benzenesulfanohydrazide (0.300g, 0.00081mol) for 5 hours afforded green powder as a product. Yield =70 %, m.pt=230 °C.

**Elemental Analysis:**

Found: C(38.45%) ; H(3.11%) ; N(4.53%)

Theory: C(37.76%) ; H(3.34%) ; N(5.50%)

**IR Spectra (KBr)**

1595cm\(^{-1}\) ( \(\nu\) C=N), 1321cm\(^{-1}\) ( \(\nu\) S=O), 1158cm\(^{-1}\) ( \(\nu\) S=O), 1090cm\(^{-1}\) ( \(\nu\) C-O), 1037cm\(^{-1}\) ( \(\nu\) N-N), 455cm\(^{-1}\) ( \(\nu\) M-N), 574cm\(^{-1}\) ( \(\nu\) M-O)

\[\text{Zn(BrHapBsh)\textsubscript{2}}\text{H}_2\text{O}\]

Zinc(II) acetate (0.089g, 0.00041 mol) was refluxed in basified ethanol (50mL) with 2’- (5-bromo -2-hydroxybenzylidene) benzenesulfanohydrazide (0.300g, 0.00081mol) for 5 hours afforded yellow solid as a product. Yield =65 %, m.pt=160 °C.

**Elemental Analysis:**

Found: C(39.72%) ; H(3.35%) ; N(5.32%)

Theory: C(38.12%) ; H(2.93%) ; N(6.32%)

**IR Spectra (KBr)**
3232cm⁻¹ (ν N-H), 1601cm⁻¹ (ν C=N), 1322cm⁻¹ (ν S=O), 1158cm⁻¹ (ν S=O), 1080cm⁻¹ (ν C=O), 1021cm⁻¹ (ν N-N), 497cm⁻¹ (ν M-N), 577cm⁻¹ (ν M-O).

\[ \text{[Ni(BrHapBsh)]}_2 \]

Nickel(II) acetate (0.089g, 0.00041mol) was refluxed in basified ethanol (50mL) with 2’-(5-bromo-2-hydroxybenzylidene) benzenesulfanohydrazide (0.300g, 0.00081mol) for 5 hours afforded yellow solid as a product. Yield =65 %, m.pt=160 °C.

**Elemental Analysis:**

Found: C(40.75%) ; H(3.44%) ; N(5.82%)

Theory: C(39.50%) ; H(2.80%) ; N(6.55%)

**IR Spectra (KBr)**

3231cm⁻¹ (ν N-H), 1561cm⁻¹ (ν C=N), 1321cm⁻¹ (ν S=O), 1158cm⁻¹ (ν S=O), 1081cm⁻¹ (ν C=O), 1024cm⁻¹ (ν N-N), 441cm⁻¹ (ν M-N), 514cm⁻¹ (ν M-O)

**¹H NMR (DMSO)**

12.96ppm [δ( NH), 1H, s], 6.70-7.78ppm [δ( aromatic), m], 2.17ppm [δ(-CH₃), 3H, s]

**¹³C {¹H} NMR (DMSO)**

156.89ppm δ( C=N), 141.82 ppm δ( C-O), 104.30-131.62ppm δ( aromatic), 13.33ppm δ(-CH₃).
Cd(methHapBsh)$_2$

A solution of cadmium(II) acetate (0.088g, 0.00033mol) in basified ethanol (30mL) was added over a solution of 2’- (5-methyl -2-hydroxybenzylidene) benzenesulfonohydrazide (0.20g,0.00066mol) in the same solvent (30mL). The mixture was refluxed in room temperature for 5 hours. The product precipitated as an yellow solid. Yield =60%, m.pt=160°C.

**Elemental Analysis:**

Found: C(51.99%) ; H(4.77%) ; N(7.99%)

Theory: C(50.11%) ; H(4.18%) ; N(7.79%)

**IR Spectra (KBr)**

3242cm$^{-1}$ (ν N-H), 1561cm$^{-1}$ (ν C=N), 1323cm$^{-1}$ (ν S=O), 1171cm$^{-1}$ (ν S=O), 1129cm$^{-1}$

(ν C-O), 1070cm$^{-1}$ (ν N-N), 409cm$^{-1}$ (ν M-N), 557cm$^{-1}$ (ν M-O)

**$^1$H NMR (DMSO)**

12.97ppm [δ(NH), 1H, s], 6.59-7.76ppm [δ( aromatic), m], 2.48ppm [δ(-CH$_3$), 3H, s],

1.87ppm [δ(Ar -CH$_3$), 3H, s]

**$^{13}$C {$^1$H} NMR (DMSO)**

155.67ppm δ(C=N), 116.08-130.93ppm δ( aromatic), 20.33ppm δ(-CH$_3$), 12.83ppm (δAr-CH$_3$)
A solution of copper(II) acetate (0.088g, 0.00033mol) in basified ethanol (30mL) was added over a solution of 2’- (5-methyl -2-hydroxybenzylidene) benzenesulfanohydrazide (0.20g, 0.00066mol) in the same solvent (30mL). The mixture was refluxed in room temperature for 5 hours. The product precipitated as an yellow solid. Yield =60%, m.pt=160°C.

**Elemental Analysis:**

Found: C(48.59%) ; H(3.70%) ; N(7.40%)

Theory: C(49.11%) ; H(4.09%) ; N(7.64%)

**IR Spectra (KBr)**

1579cm⁻¹(ν C=N), 1286cm⁻¹(ν S=O), 1151cm⁻¹(ν S=O), 1136cm⁻¹(ν C-O), 1049cm⁻¹(ν N-N), 498cm⁻¹, 581cm⁻¹ (ν M-N).

**¹H NMR (DMSO)**

5.79-8.38ppm [δ(aromatic), m] , 2.49ppm [δ(-CH₃), 3H, s] , 2.17ppm [δ(Ar -CH₃), 3H, s]

**¹³C {¹H} NMR (DMSO)**

145.43ppm δ(C=N), 106.73-123.456ppm δ( aromatic), 10.25ppm δ(-CH₃), 4.71ppm δ(Ar-CH₃)

[**[Ni(methHapBsh)]₂(H₂O)₂**]
A solution of nickel(II) acetate (0.123g, 0.00049mol) in basified ethanol (30mL) was added over a solution of 2’-(5-methyl-2-hydroxybenzylidene) benzenesulfanohydrazide (0.30g, 0.00099mol) in the same solvent (30mL). The mixture was refluxed in room temperature for 5 hours. The product precipitated as an yellow solid. Yield =60%, m.pt=160°C.

**Elemental Analysis:**

Found: C(48.59%) ; H(3.70%) ; N(7.41%)

Theory: C(47.43%) ; H(4.48%) ; N(7.38%)

**IR Spectra (KBr)**

1560cm⁻¹ (ν C=N), 1323cm⁻¹ (ν S=O), 1163cm⁻¹ (ν S=O), 1131cm⁻¹ (ν C-O), 1072cm⁻¹ (ν N-N), 418cm⁻¹ (ν M-N), 568cm⁻¹ (ν M-O)

**¹H NMR (DMSO)**

6.60-7.76ppm [δ( aromatic), m], 2.26ppm [δ(-CH₃), 3H, s], 2.17ppm [δ(Ar-CH₃), 3H, s]

**¹³C {¹H} NMR (DMSO)**

155.44ppm δ(C=N), 116.12-131.45ppm δ( aromatic), 20.18ppm δ(-CH₃),13.17ppm (δAr-CH₃)

[Zn(methHapBsh)]₂H₂O
A solution of zinc(II) acetate (0.108g, 0.00049mol) in basified ethanol (30mL) was added over a solution of 2'- (5-methyl -2-hydroxybenzylidene) benzenesulfanohydrazide (0.30g, 0.00099mol) in the same solvent (30mL). The mixture was refluxed at room temperature for 5 hours. The product precipitated as an yellow solid. Yield =60%, m.pt=150°C.

**Elemental Analysis:**

Found: C(53.22%) ; H(5.07%) ; N(8.03%)

Theory: C(52.22%) ; H(4.64%) ; N(8.12%)

**IR Spectra (KBr)**

3242cm⁻¹ (ν N-H), 1584cm⁻¹ (ν C=N), 1323cm⁻¹ (ν S=O), 1169cm⁻¹ (ν S=O), 1132cm⁻¹ (ν C-O), 1071cm⁻¹ (ν N-N), 468cm⁻¹ (ν M-N), 557cm⁻¹ (ν M-O)

**¹H NMR (DMSO)**

11.9ppm [δ(NH), 1H, s], 6.68-7.86ppm [δ( aromatic), m], 2.30ppm [δ(-CH₃), 3H, s], 1.89ppm [δ(Ar -CH₃), 3H, s]

**¹³C {¹H} NMR (DMSO)**

155.43ppm δ(C=N), 116.50-139.96ppm δ( aromatic), 20.18ppm δ(-CH₃), 13.99ppm (δAr-CH₃)
2.2: The biological activities:

i- Acute toxicity studies:

Acute toxicity studies were performed on mice (40g weight). The groups were consisted of 5 animals each. The experimental animals received the extract at a single dose of 5000mg/kg animal weight. The animals were observed carefully after 30 minutes, 240 minutes, 24 hours and after 14 days after the treatment. This method was described by (Marcio et al., 2006)

Preparation of 10% tween 20:

Tween 20 is known generally as \{Polyoxyethylene(20)sorbitol monolaurale\}. It was obtained from Biochemistry laboratory, Department of Molecular Biology, Faculty of Medicine, University of Malaya, Kuala Lumpur.

10% tween 20 buffer was prepared by adding tween 20 solution into sterile distilled water in a ratio of 1:10. About 1.8ml of tween 20 was pipetted into falcon tube and 16.2ml of distilled water was added to the solution. The mixture was mixed using a vortex mixture until well dissolved.

Preparation of the extract:

The Schiff base was dissolved in a mixture of tween 20 and distilled water in ratio of 1:10. The dose of the extract were prepared (5000mg/kg) by weighing 0.9g of the solid Schiff bases and then dissolved in (18ml) of 10% tween 20 solution. The solution was mixed by using a vortex mixture. The solution was fed to the rats according to the body weight.

ii- Anti-ulcerogenic studies:

Experimental animals:

The prevention of gastric ulcer produced by alcohol was described by (Andre R. et al., 1979). Male and female Sprague-Dawley rats, weighing 170-200g, were used in this study. Animals were transferred from animal house to animal laboratory, Faculty of medicine, University of Malaya. The rats were placed individually in cages and were provided with standard food
and water ad libitum. They were maintained at constant temperature (23±1°C) and in 12 h light-dark cycle.

**Preparation of Cimetidine:**

Cimetidine was obtained from University of Malaya Medical Centre, Kuala Lumpur.

A (50mg) of Cimetidine was weighed and put into a falcon tube. Then (7ml) of distilled water was pipetted in the tube and the mixture was mixed by using vortex.

**Preparation of the extract:**

The Schiff base was dissolved in a mixture of tween 20 and distilled water in ratio of 1:10.

Two doses of the extract were prepared for high dose (250mg/kg) by weighing 0.3g of the solid Schiff bases and was dissolved in (12ml) of 10% tween 20 solution. The low dose was prepared (62.5mg/kg) by using 0.075g the Schiff bases dissolved in (12ml) of 10% tween 20 solution. The solutions were dissolved by using a vortex.
Experimental procedure in animal study:

<table>
<thead>
<tr>
<th>24 Sprague-Dawley rats (170-200g) were divided into 4 groups</th>
</tr>
</thead>
<tbody>
<tr>
<td>Individually caged given standard pellet diet and free water</td>
</tr>
<tr>
<td>Fasting for 48 hours prior to starting the experiment and had water ad libitum.</td>
</tr>
</tbody>
</table>

**Oral pre-treatment:**
- **G1:** 2ml 10% tween 20 (ulcerated group)
- **G2:** 2ml Cimetidine (reference drug)
- **G3:** 2ml High dose extract (250mg/kg)
- **G4:** 2ml Low dose extract (62.5mg/kg)

<table>
<thead>
<tr>
<th>30 minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Administration of (1ml) absolute ethanol to induce ulcer</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>30 minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rats were killed in Diethyl ether. Stomachs were removed and gastric juice was collected</td>
</tr>
</tbody>
</table>

- Macroscopic Examination
- Microscopic Examination
**Macroscopic Examination:**

The abdomens of the rats were opened and the pylorus of each was ligated. The stomachs were removed and the gastric juice was obtained from each stomach. The surface area (mm$^2$) covered by each lesion was measured (Murakamu et al., 1990) and the sum of erosion areas per rat stomach was calculated by using microscope at magnification X1.8. Percentage ulcerated surface (US), was calculated as: $US(\text{mm}^2) = (\text{total area covered by ulcers ÷ total corpus mucosal surface}) \times 100$. The ulcer index (UI) for each animal was then calculated as the mean ulcer score. Percentage inhibition (%I) was determined as $[(\text{UI in control} - \text{UI in test group}) ÷ \text{UI in control group}] \times 100$ (Njar et al., 1995).

After the stomach contents was collected, it was centrifuge and gastric juice was separated from the mucus. The mucus was weighed and the gastric juice was used to determine the gastric acidity (Paul V. et al., 1996). The gastric acidity was measured by analyzing for hydrogen ion concentration by titrating the diluted juice (50.00ml of distilled water was added to the juice) against a 0.01M solution of NaOH, using a digital PH meter. The acid content was expressed as molarity (Paul V. et al., 1996).

**Microscopic Examination (histology examination):**

The stomach were cut into small pieces of tissues and fixed in 10% buffered formalin overnight. The tissues were processed in automated tissue processor through dehydration, cleaning and impregnation step. After that the tissues were embedded in paraffin wax and sectioned into 5μm thick section by votary microtome. The sections were stained with Haematoxylin and Eosin. Each one was analyzed under light microscope at x10, x40 and x100 magnification to observe if any changes in the tissues structure compared to the control group.
Statistical analysis data:

The results were expressed as mean ± S.E.M (standard error of the mean). The statistical difference of each group of rats were calculated using students't-test SPSS for windows evaluation version 14. The significance difference was accepted at P<0.05. Data were presented as mean ± S.E.M (M. Khayyal et al., 2006)
Chapter 3

Results and Discussions
3.1- 2’- [1-(2-Hydroxyphenyl)ethylidene]benzenesulfanohydrazide

The ligand (3.1) was prepared by acidified ethanol solution of benzenesulfanohydrazide with 2-hydroxyacetophenone (1:1). All the complexes of this ligand were prepared by mixing basified solution of the ligand and metal (II) acetate (3:1). Table 3.1 shows the elemental analytical data for the ligand and its complexes agree with the theoretical data.

Table 3.1
Elemental analytical data of the ligand [HapBsh] and its Cd(II), Cu(II) and Ni(II) complexes:

<table>
<thead>
<tr>
<th>Compound</th>
<th>C%</th>
<th>H%</th>
<th>N%</th>
</tr>
</thead>
<tbody>
<tr>
<td>HapBsh</td>
<td>57.93(57.85)</td>
<td>4.86(4.90)</td>
<td>9.65(9.87)</td>
</tr>
<tr>
<td>Cd(HapBsh)₂</td>
<td>47.67(50.07)</td>
<td>3.77(3.20)</td>
<td>8.11(9.55)</td>
</tr>
<tr>
<td>[Cu(HapBsh)]₂</td>
<td>47.65(45.37)</td>
<td>3.68(3.34)</td>
<td>7.94(6.41)</td>
</tr>
<tr>
<td>Ni(HapBsh)₂</td>
<td>52.77(51.36)</td>
<td>4.08(5.07)</td>
<td>8.79(7.25)</td>
</tr>
</tbody>
</table>

Table 3.2:
IR- spectra of the ligand and its Cd(II), Cu(II) and Ni(II) complexes:

<table>
<thead>
<tr>
<th>Compounds</th>
<th>ν(Ar-OH)</th>
<th>ν(N-H)</th>
<th>ν(C=N)</th>
<th>ν(S=O)</th>
<th>ν(C-O)</th>
<th>ν(N-N)</th>
<th>ν(M-O)</th>
<th>ν(M-N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HapBsh</td>
<td>3444</td>
<td>3235</td>
<td>1607</td>
<td>1352, 1164</td>
<td>1084</td>
<td>1022</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Cd(HapBsh)₂</td>
<td>-</td>
<td>3235</td>
<td>1600</td>
<td>1299, 1164</td>
<td>1085</td>
<td>1035</td>
<td>508</td>
<td>400</td>
</tr>
<tr>
<td>[Cu(HapBsh)]₂</td>
<td>-</td>
<td>3430</td>
<td>1592</td>
<td>1329, 1164</td>
<td>1085</td>
<td>1038</td>
<td>504</td>
<td>442</td>
</tr>
<tr>
<td>Ni(HapBsh)₂</td>
<td>-</td>
<td>3172</td>
<td>1600</td>
<td>1353, 1164</td>
<td>1087</td>
<td>1035</td>
<td>503</td>
<td>441</td>
</tr>
</tbody>
</table>
**IR-spectrum of ligand:**

IR spectrum shows two bands at 3444 and 3235 cm\(^{-1}\) assignable to \(\nu\) (OH) phenolic and \(\nu\) (N-H) respectively. The decreasing in \(\nu\) (-OH) wavenumber in the ligand than the free \(\nu\) (-OH) group (3700-3500 cm\(^{-1}\)) is because of participation of (OH) group in intermolecular or intramolecular hydrogen bond (Tawfik et al., 1989) as will be discussed later according to the x-ray structure (Figure 3.3). Strong band of azomethine group (C=N) occurred at 1607 cm\(^{-1}\). This group has occurred from the condensation reaction between (NH\(_2\)) and carbonyl (C=O) group. There are two bands at 1353 cm\(^{-1}\) and 1164 cm\(^{-1}\) which are assigned to two (S=O) groups. The infrared spectral vibration modes are listed in table 3.2.

**NMR spectrum data of the ligand:**

**Table 3.3:**

\(^1\)H NMR data of the ligand and its Cd(II) and Ni(II) complexes:

<table>
<thead>
<tr>
<th>Compounds</th>
<th>(\delta) (OH)</th>
<th>(\delta) (NH)</th>
<th>(\delta) (Arom.)</th>
<th>(\delta) (CH(_3))</th>
</tr>
</thead>
<tbody>
<tr>
<td>HapBsh</td>
<td>11.59</td>
<td>11.07</td>
<td>6.807-7.9</td>
<td>2.27</td>
</tr>
<tr>
<td>Cd(HapBsh)(_2)</td>
<td>-</td>
<td>12.19</td>
<td>6.74-7.82</td>
<td>2.21</td>
</tr>
<tr>
<td>Ni(HapBsh)(_2)</td>
<td>-</td>
<td>12.93</td>
<td>6.70-7.74</td>
<td>2.16</td>
</tr>
</tbody>
</table>

The \(^1\)H NMR spectrum of the ligand (Figure 3.1) shows the \(\delta\)-(OH) and \(\delta\)(N-H) group protons at 11.59 ppm and 11.08 ppm respectively, with integration values corresponding to one proton for each one. A singlet peak appeared at lower frequency at 2.27 ppm with integration to three protons was assigned to methyl group (CH\(_3\)). The benzene rings protons were appeared in range of (6.81-7.90 ppm).
Figure 3.1: The \(^1\text{H}\) NMR spectrum of HapBsh

Table 3.4: \(^{13}\text{C}\{^1\text{H}\}\) NMR data of the ligand and its Cd(II) and Ni(II) complexes:

<table>
<thead>
<tr>
<th>Compounds</th>
<th>(\delta)(C=N)</th>
<th>(\delta)(C-O)</th>
<th>(\delta)(Arom.)</th>
<th>(\delta)(CH3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HapBsh</td>
<td>158.70</td>
<td>157.52</td>
<td>116.9-138.28</td>
<td>14.65</td>
</tr>
<tr>
<td>Cd(HapBsh)(_2)</td>
<td>156.20</td>
<td>156.17</td>
<td>117-133</td>
<td>14.49</td>
</tr>
<tr>
<td>Ni(HapBsh)(_2)</td>
<td>157.76</td>
<td>-</td>
<td>116.33-131.35</td>
<td>13.13</td>
</tr>
</tbody>
</table>

The \(^{13}\text{C}\{^1\text{H}\}\) NMR spectrum of the ligand (Figure 3.2) shows signals at 158.70 ppm which are due to azomethine carbon (C=N). The carbon (C-OH) has appeared at 157.53 ppm. The spectrum shows the aromatic carbons in the region of 116.92-138.28 ppm.
Figure 3.2: The $^{13}$C-$^1$H NMR spectrum of HapBsh

X-ray data of the ligand:

According to x-ray structure showed in (Figure 3.3), the compound 2’-[1-(2-hydroxyphenyl)ethylidene]benzenesulfanohydrazide was first described by Kotali(1993), similarly has its hydroxyl group involved in an intramolecular hydrogen bond, and adjacent molecules are also linked by a hydrogen bond [N-O = 2.980 (2) Å] into a chain; however, the repeat distance is somewhat lengthened to (5.18 Å), owing to the bulky of the methyl group. The amino –NH- part of the molecule has the (N) atom in a pyramidal configuration; that in salicylaldehyde p-toluenesulfanohydrazone is unknown as the equivalent H atom was not located (Hapipah et al., 2007)
IR-spectra of complexes:

In order to give conclusive idea about the structure of the metal complexes, the main IR bands were compared with those of free ligand (Table 3.2). The (OH) stretching frequency appearing in the spectra of all complexes as a broad bands in range of 3430 cm\(^{-1}\)-3440 cm\(^{-1}\) is due to the presence of hydration water, which was confirmed by thermal analysis located outside the coordination sphere (Abdel-Ghani et al., 1989). The ligand displays the \(\nu\)\((C=N)\) band at 1607 cm\(^{-1}\). Upon chelation, a shift to a lower wavenumber has been observed, indicating a decrease in the bond order due to the coordination of the metal atom to the azomethine nitrogen lone pair. This small shift value of shift in \(\nu\)\((C=N)\) was reported in the studies (Xiao et al., 2000). The increase in the wavenumber of \(\nu\)\((N-N)\) is an evidence of this coordination. The spectra of the complexes show that \(\nu\)\((OH)\) phenolic bands have dissapeared indicating coordination of this group to the metal center.
Figure 3.4: The IR spectrum of Ni(HapBsh)$_2$

Figure 3.5: The IR spectrum of Cd(HapBsh)$_2$
The IR spectrum of Cu(II) complex (Figure 3.6) when compared to that of free ligand shows that the sharp beak of (N-H) has disappeared and buried with the (OH) stretching frequency, so it did not take part in coordination with the metal ion. There are two bands within the wavenumber range of 1299 cm\(^{-1}\) – 1164 cm\(^{-1}\) assigned to two (S=O ) groups. The new bands in ranges of 400-442 cm\(^{-1}\) and 500-508 cm\(^{-1}\) were assigned as \(\nu\) (M-N) and \(\nu\) (M-O) bonds respectively. According to elemental analysis and TGA measurement, the molecule of Cu(II) complex is dimeric via phenolic oxygen bridges. This feature is obtained by (Hapipah et al., 2004)

![Figure 3.6: The IR spectrum of [Cu(HapBsh)]\(_2\)](image)

**H\(^1\) N.M.R. data of the complexes:**

H\(^1\) N.M.R. spectra of the complexes show the \(\delta\)(OH) phenolic peaks which appear at 11.59 ppm in the ligand has disappeared indicating coordination of this groups to metal center. The \(\delta\)(N-H) protons resonance has appeared at 12.19-12.93 ppm in Cd(II) and
Ni(II) complexes respectively. The spectra show singlet peaks appeared at lower frequency in range 2.16- 2.20 ppm with integration to three protons was assigned to methyl group (CH₃). The benzene ring protons resonate in the range of 6.70-7.9 ppm.

**¹³C{¹H}NMR data of the complexes:**

Further support for the proposed structures of the Cd(II) and Ni(II) complexes was provided by ¹³C{¹H}NMR spectra. The peaks at 156.20 ppm and 157.77 ppm could be assigned to azomethine carbon C=N in Cd(II) and Ni(II) complexes respectively. The ¹³C{¹H}NMR data showed clearly the methyl group as single peak at 13.13 and 14.49 ppm. The signals at 116.33-133 ppm are assigned to carbons of the phenyl rings. Figure 3.7 shows ¹³C{¹H}NMR spectrum of Ni(II) complex. The structures of the complexes was further determined by UV and TGA. However NMR spectra of Cu(II) complex were not measured due to low solubility in DMSO.

**Figure 3.7:** The ¹³C{¹H}NMR spectrum of Ni(HapBsh)₂
UV-visible spectral data:

Table 3.5:
Electronic absorption spectra of the ligand and its Cd(II), Cu(II) and Ni(II) complexes in the UV region:

<table>
<thead>
<tr>
<th>Compound</th>
<th>$\lambda$ (nm)</th>
<th>$M \rightarrow \pi \pi^*$</th>
<th>$n \rightarrow \pi^*$</th>
<th>LMCT</th>
<th>d-d</th>
</tr>
</thead>
<tbody>
<tr>
<td>HapBsh</td>
<td>$10^{-4}$</td>
<td>235, 255, 275</td>
<td>310</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Cd(HapBsh)$_2$</td>
<td>$10^{-3}$</td>
<td>235, 255, 265</td>
<td>285</td>
<td>315, 345</td>
<td>-</td>
</tr>
<tr>
<td>[Cu(HapBsh)$_2$</td>
<td>$10^{-4}$</td>
<td>205, 220, 240, 270</td>
<td>290, 300</td>
<td>345, 360</td>
<td>-</td>
</tr>
<tr>
<td>Ni(HapBsh)$_2$</td>
<td>$10^{-3}$</td>
<td>215, 230, 250</td>
<td>290</td>
<td>340, 395</td>
<td>670</td>
</tr>
</tbody>
</table>

The electronic absorption data of the compounds, are given in Table 3.5. In the spectrum of the ligand (3.1), the shoulder band in the 310 nm was assigned to the $n \rightarrow \pi^*$ transition of the azomethine group. The intense bands in the 235-275 nm range are attributed to the $\pi \rightarrow \pi^*$ transition of the azomethine group and benzene ring. In the complexes, these bands are shifted to lower wavelengths. In the spectra of the complexes the less intense and broad bands in the range of 395-315 nm result from the overlapping of the low energy $\pi \rightarrow \pi^*$ transitions mainly localized within the imine chromophore and the LMCT (ligand to metal charge transfer bands) transition from the lone pairs of the phenolic oxygen donor to the M(II) ions (Somez et al., 2002). The band at 310 nm in the ligand which assigned to the $n \rightarrow \pi^*$ transition of the azomethine group, have shifted, after complexation to lower wavelengths between 285 to 300 nm range suggesting that the nitrogen atom of the azomethine group is coordinated to the metal ion. The other high energy transition observed as strong bands in the range of 215-270 nm is
assigned to the $\pi \rightarrow \pi^*$ transition of the benzene ring and azomethine group. The expected d-d transition in the visible region for complexes of the ligand (3.1) cannot be detected even with concentrated solution. It may be lost in the low energy tail of the charge transfer transition (Nashar or Maiti et al., 2004l). The Ni(II) complex, of the ligand (3.1) shows more red shift and appears at 215-250 nm.

**Thermal studies:**

The weight loss was measured from 30°C up to ≈ 900°C. The weight losses for each chelate were calculated for the corresponding temperature and are shown in table 3.6.

**Table 3.6:**  
TGA data of the Cd(HapBsh)$_2$, [Cu(HapBsh)]$_2$ and Ni(HapBsh)$_2$:

<table>
<thead>
<tr>
<th>Complex</th>
<th>Step</th>
<th>Temperature (°C)</th>
<th>Weight loss (%) Found(Calculated)</th>
<th>Assignment</th>
<th>Residue (%) Found(Calculated)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cd(II)</td>
<td>1</td>
<td>29.52-58.30</td>
<td>3.78(2.61)</td>
<td>H$_2$O</td>
<td>18.64(18.60)</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>170.22-216.22</td>
<td>13.52(13.33)</td>
<td>Ph-O</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>217.75-315.87</td>
<td>60.20(60.25)</td>
<td>(Ph-SO$_2$-NH-N)$_2$, Ph</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>397.18-538.18</td>
<td>7.64(7.82)</td>
<td>(C-CH$_3$)$_2$</td>
<td></td>
</tr>
<tr>
<td>Cu(II)</td>
<td>1</td>
<td>30.00-83.42</td>
<td>6.41(5.10)</td>
<td>2H$_2$O</td>
<td>31.865(27.11)</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>142.95-222.32</td>
<td>20.47(21.15)</td>
<td>(Ph)$_2$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>219.26-289.47</td>
<td>17.65(20.14)</td>
<td>[C(CH$_3$)=N-NH$_2$O]$_2$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>291.00-492.47</td>
<td>30.01(30.90)</td>
<td>(Ph-S)$_2$</td>
<td></td>
</tr>
<tr>
<td>Ni(II)</td>
<td>1</td>
<td>29.25-77.92</td>
<td>6.33(5.65)</td>
<td>2H$_2$O</td>
<td>16.6(14.24)</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>77.92-128.06</td>
<td>3.80(4.24)</td>
<td>C-CH$_3$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>128.06-268.43</td>
<td>52.27(53.40)</td>
<td>(Ph-SO$_2$-NH-N)$_2$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>267.00-305.67</td>
<td>10.13(11.94)</td>
<td>Ph-</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>302.48-818.50</td>
<td>17.18(16.17)</td>
<td>Ph-C-CH$_3$</td>
<td></td>
</tr>
</tbody>
</table>
The weight loss was measured from 30 °C up to ≈ 900 °C. The weight losses for each chelate were calculated for the corresponding temperature ranges and are shown in table 3.6. The metal percentages calculated from metal oxide residues were compared with those determined by the analytical metal content determination (Macdonald et al., 1969).

The Cd(II) complex was stable up to 29.52 °C and its decomposition started at this temperature and was completed at 538.18 °C. A mass loss has occurred within the temperature range 29.52-58.30 °C corresponding to the loss of hydrated water molecule. The Cd(II) complex decomposed and produced CdO residue [found(calculated)%: 18.64(18.60)] in four steps in the temperature range 29.52-58.30, 170.22-216.22, 217.75-315.87 and 397.18-538.18 °C. In the decomposition process of Cd(II) complex, the mass losses corresponded to H₂O, ph-O, (ph-SO₂-NH-N)₂.ph and (C-CH₃)₂ respectively (figure 3.8)

![Figure 3.8: The TGA spectrum of Cd(HapBsh)₂](image)
The Cu(II) complex was stable up to 30.00 °C and its decomposition started at this temperature and was completed at 492.47 °C. A mass loss occurred within the temperature range 30.00-83.42 °C corresponding to the loss of two hydrated water molecules. The Cu(II) complex decomposed and produced CuO₂ as residue [found(calculated)%: 31.87(27.11)] in four steps in the temperature range 30.00-83.42, 142.95-222.32, 219.26-289.47 and 291.00-492.47°C respectively. In the decomposition process of Cu(II) complex, the mass losses corresponded to 2H₂O, (ph)₂, [(CH₃C=N-NH).O]₂ and (ph-S)₂ respectively (Figure 3.9).

**Figure 3.9:** The TGA spectrum of [Cu(HapBsh)]₂

The Ni(II) complex was stable up to 29.25 °C and its decomposition started at this temperature and was completed at 818.50 °C. A mass loss occurred within the temperature range 29.25-77.92 °C corresponding to the loss of two hydrated water molecules. The Ni(II) complex decomposed and produced NiO₂ as residue [found(calculated)%: 16.6(14.24)] in five steps in the temperature range 29.25-77.92,
77.92-128.06, 128.06-268.43, 267.00-305.77 and 402.48-818.50 °C respectively. In the decomposition process of Ni (II) complex, the mass losses corresponded to 2H₂O, C-CH₃, (ph-SO₂-NH-N)₂, ph- and ph-C-CH₃ respectively (Figure 3.10).

**Figure 3.10:** The TGA spectrum of Ni(HapBsh)₂

The Cd(II), Cu(II) and Ni(II) complexes are thermally stable up to around 30 °C. In the TGA curves of these complexes, 3.78%, 6.41% and 6.33% respectively, weight loss was observed. This shows that the complexes contain 1, 2 and 2 moles of water per complex molecule, respectively. The IR spectra of the complexes are characterized by the appearance of a broad band in the region 3436-3442cm⁻¹, due to the ν (-OH) of the water (Sekerci et al., 2000). This water was not identified by the elemental analyses confirming the location of water molecules outside the complex structure. As it can be seen in Table 3.6, Cd(II), Cu(II) and Ni(II) complexes are at the same stability.
Proposed structures of the (HapBsh) metal complexes:

The structures of the metal complexes were proposed as they are in good agreement to elemental analysis, IR, NMR, UV and TGA.

3. 2- 2’- (5-Chloro-2-hydroxybenzylidene)benzenesulfanohydrazide

The ligand (3. 2) was prepared by acidified ethanol solution of benzenesulfanohydrazide with 5’-chloro-2’-hydroxyacetophenone (1:1). All the complexes of this ligand were prepared by mixing basified solution of the ligand and metal (II) acetate (2:1). Table 3.7
shows the elemental analytical data for the ligand and its complexes agree with the theoretical data.

**Table 3.7:**
Elemental analytical results of the ligand and Cu(II) and Ni(II) complexes:

<table>
<thead>
<tr>
<th>Compound</th>
<th>Calculated (found)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>C%</td>
</tr>
<tr>
<td>ClHapBsh</td>
<td>51.72(51.83)</td>
</tr>
<tr>
<td>[Cu(ClHapBsh)]_2</td>
<td>43.96(42.22)</td>
</tr>
<tr>
<td>[Ni(ClHapBsh)]_2</td>
<td>43.96 (42.22)</td>
</tr>
</tbody>
</table>

**Table 3.8:**
IR- spectra of the ligand and its Cu(II) and Ni(II) complexes:

<table>
<thead>
<tr>
<th>Compounds</th>
<th>v(Ar-OH)</th>
<th>v(N-H)</th>
<th>v(C=N)</th>
<th>v(S=O)</th>
<th>v(C-O)</th>
<th>v(N-N)</th>
<th>v(M-O)</th>
<th>v(M-N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ClHapBsh</td>
<td>3423</td>
<td>3232</td>
<td>1603</td>
<td>1324, 1158</td>
<td>1074</td>
<td>1020</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>[Cu(ClHapBsh)]_2</td>
<td>-</td>
<td>3232</td>
<td>1579</td>
<td>1322, 1158</td>
<td>1099</td>
<td>1036</td>
<td>517</td>
<td>424</td>
</tr>
<tr>
<td>[Ni(ClHapBsh)]_2</td>
<td>-</td>
<td>3232</td>
<td>1541</td>
<td>1324, 1158</td>
<td>1096</td>
<td>1039</td>
<td>578</td>
<td>497</td>
</tr>
</tbody>
</table>

**IR-spectrum of ligand:**

The IR spectrum of the ligand (Figure 3.11) shows a weak \( \nu \) (ph-OH) band at 3423 cm\(^{-1}\) and shows strong sharp \( \nu \) (N-H) band at 3232 cm\(^{-1}\). The decreasing in \( \nu \) (-OH)
wavenumber in the ligand than the free $\nu$ (-OH) group (3700-3500 cm$^{-1}$) indicating that the OH in such hydrazones is probably involved in the formation of strong intramolecular hydrogen bond as shown in x-ray structure later in Figure 3.9. This result was reported elsewhere (Tawfik et al., 1989). The strong band at 1603 cm$^{-1}$ is assigned to the imine, $\nu$(C=N) group. There are two bands at 1324 cm$^{-1}$ and 1158 cm$^{-1}$ assigned to two (S=O ) groups (Figure 3.11).

![Image of IR spectrum with annotations]

**Figure 3.11:** The IR spectrum of ClHapBsh

**NMR spectrum data of the ligand:**

**Table 3.9:**
$^1$H NMR data of the ligand and its Cu(II) complex:

<table>
<thead>
<tr>
<th>Compounds</th>
<th>$\delta$(OH)</th>
<th>$\delta$(NH)</th>
<th>$\delta$(Arom.)</th>
<th>$\delta$(CH3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ClHapBsh</td>
<td>11.43</td>
<td>11.19</td>
<td>6.84-7.88</td>
<td>2.07</td>
</tr>
<tr>
<td>[Cu(ClHapBsh)]$_2$</td>
<td>-</td>
<td>11.63</td>
<td>6.80-7.80</td>
<td>2.2</td>
</tr>
</tbody>
</table>
The $^1$H NMR spectrum showed that the $\delta$(-OH) and $\delta$(N-H) groups protons at 11.43 ppm and 11.19 ppm respectively, with integration values corresponding to one proton each. A singlet peak appeared at lower frequency at 2.07 ppm with integration to three protons was assigned to methyl group $\delta$(CH$_3$). The benzene rings protons appeared in the range of (6.84-7.89 ppm).

**Table 3.10:**
$^{13}$C{$^1$H}NMR data of the ligand and its Cu(II) complex:

<table>
<thead>
<tr>
<th>Compounds</th>
<th>$\delta$(C=N)</th>
<th>$\delta$( C-O)</th>
<th>$\delta$( Arom.)</th>
<th>$\delta$( CH3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ClHapBsh</td>
<td>157.09</td>
<td>156.12</td>
<td>118.7-138.45</td>
<td>14.86</td>
</tr>
<tr>
<td>[Cu(ClHapBsh)]$_2$</td>
<td>158.74</td>
<td>155.97</td>
<td>118.0-138.0</td>
<td>14.64</td>
</tr>
</tbody>
</table>

The $^{13}$C{$^1$H}NMR spectrum of the ligand (3.2 ) in Figure 3.12, showed signals due to azomethine carbon (C=N) at 159.09 ppm and the (C-OH) carbon had appeared at 157.09 ppm. The spectrum also showed peaks in the region 118.69-138.45 ppm , due to aromatic carbons. A peak appeared at lower frequency at 14.86 ppm was assigned to methyl group (CH$_3$).
Figure 3.12: The $^{13}\text{C}\{^1\text{H}\}$NMR spectrum of ClHapBsh

x-ray data of the ligand:

Figure 3.13 is an ORTEP diagram showing the structure of the ligand, 2’- (5-chloro-2-hydroxybenzylidene)benzenesulfanohydrazide. The two molecules of the ligand are linked by two N—H----O sulfonyl hydrogen bonds about a center of inversion to furnish a hydrogen-bonded dimer. Comparatively, the molecules of 2-hydroxyacetophenone benzenesulfonohydrazide are linked by a hydrogen bond [N----O$_{\text{sulfonyl}}$ = 2.980 (2) Å] into a chain; a Cl-atom substituent in the ketone reagent furnished the related compound, but here two inversion-related molecules are linked by a pair of N—H----O$_{\text{sulfonyl}}$ hydrogen bonds [N----O = 2.929 (2) Å] to form a dimer. The amino –NH– part of the molecule has the N atom in a pyramidal configuration (Hapipah et al., 2007)
Figure 3.13:
View of the hydrogen-bonded structure of ligand (3. 2). H atoms are shown as spheres of arbitrary radius. The dashed lines represent intra- and intermolecular hydrogen bonds.

IR-spectra of complexes:

The main IR bands were compared with those of free ligand (Table 3.8). The (OH) stretching frequency appearing in the spectra of Ni(II) complex (Figure 3.14) as abroad band in range 3400 -3471cm$^{-1}$ is due to the presence of hydration water, which was confirmed by thermal analysis located outside the coordination sphere.

Figure 3.14: The IR spectrum of [Ni(ClHapBsh)]$_2$
The $\nu$(C=N) bands at wavenumber 1603 cm$^{-1}$ in the ligand has shifted to lower frequency at range of 1579 cm$^{-1}$ to 1541 cm$^{-1}$, due to the coordination nitrogen atom to the metal centre forming M-N bond. The shifting of the $\nu$ (N-N) to higher wavenumbers from 1020 cm$^{-1}$ for the ligand to maximum 1036 cm$^{-1}$ in Cu(II) complex and 1039 cm$^{-1}$ in Ni(II) complex further support coordination of the ligand via the azomethine nitrogen atom. The spectra of the complexes show that $\nu$ (OH) phenolic bands have disappeared indicating coordination of this group to the metal center. The IR spectrum of Cu(II) and Ni(II) complexes when compared to that of free ligand show that NH and SO$_2$ bands remain unaltered, indicating that these groups did not take part in coordination. The new bands in ranges 420-497 cm$^{-1}$ and 510-580 cm$^{-1}$ were assigned as $\nu$ (M-N) and $\nu$ (M-O) bonds respectively. Figure 3.15 shows IR spectra of the [Cu(ClHapBsh)]$_2$.

![Figure 3.15: The IR spectrum of [Cu(ClHapBsh)]$_2$](image)
**H¹ N.M.R. data of the complexes:**

The 11.43 ppm signal, downfield of TMS, attributed to the proton of δ(OH) (phenolic) group in the spectrum of the ligand (3. 2), is not observed in the spectrum of the Cu(II) complex indicating the participation of (OH) (phenolic) in the bonding with displacement of hydrogen atom.

**¹³C{¹H}NMR data of the complexes:**

The ¹³C{¹H}NMR spectrum further support this evidence in Cu(II) complex. The carbon attached to hydroxyl group was resonated downfield, at 155.97 ppm, while the close peak at 158.74 ppm was assigned to azomethine carbon C=N. The methyl group appeared as a single peak at 14.64ppm (Figure 3.16).

The ¹H and ¹³C{¹H}NMR spectra can not be obtained in Ni(II) complex indicating that complex is paramagnetic (*Baxter et al., 2001*)

![Figure 3.16: The ¹³C{¹H}NMR spectrum of [Cu(ClHapBsh)]₂](image-url)
UV-visible spectral data:

Table 3.11:
Electronic absorption spectra of free ligands and their metal complexes in the UV region:

<table>
<thead>
<tr>
<th>Compound</th>
<th>λ (nm)</th>
<th>M</th>
<th>π → π*</th>
<th>n → π*</th>
<th>LMCT (nm)</th>
<th>d-d</th>
</tr>
</thead>
<tbody>
<tr>
<td>ClHapBsh</td>
<td>10⁻⁴</td>
<td>235,245,259,270</td>
<td>320</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>[Cu(ClHapBsh)]₂</td>
<td>10⁻⁴</td>
<td>215,235,260</td>
<td>280,295</td>
<td>355-380</td>
<td>681</td>
<td></td>
</tr>
<tr>
<td>[Ni(ClHapBsh)]₂</td>
<td>10⁻⁴</td>
<td>210,230,245</td>
<td>260</td>
<td>345</td>
<td>670</td>
<td></td>
</tr>
</tbody>
</table>

The UV-visible data of the ligand (3.2) and its complexes were recorded in 200-800 nm in DMSO. The intense bands in 210-270 nm range which assigned to the π → π* transition (as shown in Table 3.11) involves molecular orbitals essentially localized on C=N group and phenyl ring, Thus the transition involves the azomethine group. The weak band as shoulder at 320 nm is assigned to n → π* transition involving molecular orbitals of the azomethine group chromophore. On comparing 2-hydroxyl acetophenone complexes with 5′-chloro-2′-hydroxyacetophenone the chloro complexes, the λ_max, exhibited at lower energy regions. This may be due to the deviation of metal ions from their square-basal coordination plane upon halide ion coordination.

The spectra of the Ni(II) complex shows low intensity bands at range 345 and 670 nm due to LMCT(ligand to metal charge transfer bands) transition from the lone pairs of the phenolic oxygen donor to the M(II) ions and d-d transition respectively (Somez et al., 2002). The LMCT in Cu(II) complex appeared as strong bands at 355-380 nm. Strong bands in range 260-295 nm are assigned to n → π* transition involving molecular
orbitals of the azomethine group chromophore and phenyl ring. The $\pi \rightarrow \pi^*$ transition due to the aromatic ring chromophore has shifted on coordination to higher energy in range of 215-260 nm. The nickel(II) complex has larger red shifted than Cu(II) complex comparing to the ligand (3. 2).

Thermal studies:

The Cu(II) complex was stable up to 144.96°C and its decomposition started from this temperature onward and was completed at 716.68°C. At the temperature range 144.96-325.18 °C a mass loss occurred corresponding to a loss of (Ph-CH$_3$C=N-NH)$_2$O. At the temperature range of 325.18-545.79 °C mass losses occurred due to the loss of (Ph)$_2$SO. Finally, at the temperature range 545.79-716.68°C mass losses occurred due to the loss of SO$_2$ and this continues till a constant weight is obtained where a metallic oxide residue is formed by 20.22% (Figure 3.17)

**Figure 3.17:** The TGA spectrum of [Cu(ClHapBsh)$_2$]

For Ni(II) complex (Table 3.12), a mass loss occurred within the temperature range of 68.89-121.69°C corresponding to the loss of hydrated water molecules and at the
temperature range of 136.58-179.91°C corresponding to a loss of (C-CH₃)₂N. At the temperature range of 179.91-219.17°C a mass loss occurred corresponding to a loss of (NH)₂NO. At the temperature range of 217.82-257.08°C the mass losses occurred due to loss of (Ph)₂ and the loss of (Ph-Cl.SO)₂ started from 258.44°C to 797.29°C. The decomposition continues till a constant weight was obtained where Ni₂O₃ residue was formed in 24.64% (Figure 3.18).

![Figure 3.18: The TGA spectrum of [Ni(ClHapBsh)]₂](image)

The Ni(II) complex is thermally stable up to around 68.89°C. In the TGA curve of this complex, 9.58% weight loss was observed correlating to 3 moles of water per complex molecule. The IR spectrum of the complex is indicated by the appearance of a broad band in the region 3400-3471 cm⁻¹, due to the ν(-OH) of the water. The Cu(II) complex is thermally stable up to around 144.96°C as it can be seen in Table 3.12. So the Cu(II) complex is more stable than Ni(II) complex.
Table 3.12:
TGA data of the [Cu(ClHapBsh)]$_2$ and [Ni(ClHapBsh)]$_2$:

<table>
<thead>
<tr>
<th>Complex</th>
<th>Step</th>
<th>Temperature (°C)</th>
<th>Weight loss (%) Found(Calculated)</th>
<th>Assignment</th>
<th>Residue (%) Found(Calculated)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cu(II)</td>
<td>1</td>
<td>144.96-325.18</td>
<td>46.04(45.99)</td>
<td>(Ph-CH$_3$C=N-NH)$_2$.O</td>
<td>Cu$_2$O$_2$</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>325.18-545.79</td>
<td>25.81(26.09)</td>
<td>(Ph)$_2$.SO</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>545.79-716.68</td>
<td>7.93(8.26)</td>
<td>SO$_2$</td>
<td></td>
</tr>
<tr>
<td>Ni(II)</td>
<td>1</td>
<td>68.89-121.69</td>
<td>9.58(7.07)</td>
<td>3H$_2$O</td>
<td>Ni$_2$O$_3$</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>136.58-179.91</td>
<td>8.80(8.90)</td>
<td>(C-CH$_3$)$_2$N</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>179.91-219.17</td>
<td>5.87(7.85)</td>
<td>(NH)$_2$NO</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>217.82-257.08</td>
<td>19.77(20.16)</td>
<td>(Ph)$_2$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>258.44-797.29</td>
<td>40.92(41.50)</td>
<td>(Ph-Cl.SO)$_2$</td>
<td></td>
</tr>
</tbody>
</table>

Proposed structures of the(ClHapBsh) complexes:

![Proposed structure](image)

According to thermal analysis, there are two metal atoms in the complex molecule, leading to the previous structure. The elemental analysis(C, H, N) was in good agreement with the proposed structure of the complexes. This feature is in contrast with a study...
about Ni(II) complexes was done by (Mishtu et al., 2002), wherein the di-nuclear complexes involve bridging of the phenoxy group.

3. 3- 2’- (5-Flouro -2-hydroxybenzylidene)benzenesulfanohydrazide

The ligand (3. 3) was prepared by acidified ethanol solution of benzenesulfanohydrazide with 5’-flouro -2’-hydroxyacetophenone (1:1). All the complexes of this ligand were prepared by mixing basified solution of the ligand and metal (II) acetate (2:1). Table 3.13 shows the elemental analysis data for the ligand and its complexes agree with the theoretical data.

<table>
<thead>
<tr>
<th>Compound</th>
<th>C%</th>
<th>H%</th>
<th>N%</th>
</tr>
</thead>
<tbody>
<tr>
<td>FHapBsh</td>
<td>54.48(54.56)</td>
<td>4.21(4.64)</td>
<td>9.08(9.37)</td>
</tr>
<tr>
<td>[Cd(FHapBsh)]2H2O</td>
<td>39.30(40.21)</td>
<td>2.80(3.50)</td>
<td>6.55(5.01)</td>
</tr>
<tr>
<td>[Cu(FHapBsh)]2</td>
<td>45.34(44.46)</td>
<td>3.24(3.94)</td>
<td>7.56(7.97)</td>
</tr>
<tr>
<td>[Ni(FHapBsh)]2</td>
<td>46.06(44.51)</td>
<td>3.01(4.78)</td>
<td>7.67(5.86)</td>
</tr>
<tr>
<td>Zn(FHapBsh)2</td>
<td>49.46(48.67)</td>
<td>3.53(4.27)</td>
<td>8.24(7.22)</td>
</tr>
</tbody>
</table>
Table 3.14:  
IR-spectra of the ligand and its Cd(II), Cu(II) and Ni(II) complexes:

<table>
<thead>
<tr>
<th>Compounds</th>
<th>(\nu(\text{Ar-OH}))</th>
<th>(\nu(\text{N-H}))</th>
<th>(\nu(\text{C=N}))</th>
<th>(\nu(\text{S=O}))</th>
<th>(\nu(\text{C-O}))</th>
<th>(\nu(\text{N-N}))</th>
<th>(\nu(\text{M-O}))</th>
<th>(\nu(\text{M-N}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>FHapBsh</td>
<td>3423</td>
<td>3149</td>
<td>1573</td>
<td>1325, 1161</td>
<td>1075</td>
<td>1021</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>[Cd(FHapBsh)]_2</td>
<td>-</td>
<td>3150</td>
<td>1563</td>
<td>1325, 1161</td>
<td>1126</td>
<td>1036</td>
<td>512</td>
<td>403</td>
</tr>
<tr>
<td>(\text{H}_2\text{O})</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>[Cu(FHapBsh)]_2</td>
<td>-</td>
<td>3148</td>
<td>1539</td>
<td>1322, 1163</td>
<td>1077</td>
<td>1040</td>
<td>509</td>
<td>419</td>
</tr>
<tr>
<td>[Ni(FHapBsh)]_2</td>
<td>-</td>
<td>3152</td>
<td>1570</td>
<td>1325, 1166</td>
<td>1074</td>
<td>1025</td>
<td>517</td>
<td>408</td>
</tr>
<tr>
<td>Zn(FHapBsh)_2</td>
<td>-</td>
<td>3150</td>
<td>1560</td>
<td>1325, 1162</td>
<td>1076</td>
<td>1047</td>
<td>525</td>
<td>419</td>
</tr>
</tbody>
</table>

**IR-spectrum of ligand:**

This ligand formed from reaction between benzenesulphonylhyrazide with 5-flouro-2-hydroxyacetophenone. The IR spectrum (Figure 3.19) shows a broad band at 3423 cm\(^{-1}\), which was due to \(\nu\) (OH) phenolic. The free \(\nu\) (OH) is generally observed between 3500 and 3650 cm\(^{-1}\). The observed low value of this band is due to intramolecular hydrogen bonding between H of OH and azomethine nitrogen atom (Tawfik et al., 1989). A strong band of \(\nu\) (N-H) was observed at 3149 cm\(^{-1}\). The band at 1573 cm\(^{-1}\) was assigned to \(\nu\) (C=N). The intense bands at 1325 cm\(^{-1}\) and 1161 cm\(^{-1}\) assigned to two (S=O) groups.
Figure 3.19: The IR spectrum of FHapBsh

NMR spectrum data of the ligand:

Table 3.15:
$^1$H NMR data of the ligand and its Cd(II) and Ni(II) complexes:

<table>
<thead>
<tr>
<th>Compounds</th>
<th>$\delta$(OH)</th>
<th>$\delta$(NH)</th>
<th>$\delta$(Arom.)</th>
<th>$\delta$(CH3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FHapBsh</td>
<td>11.36</td>
<td>11.19</td>
<td>6.805-7.84</td>
<td>2.22</td>
</tr>
<tr>
<td>[Ni(FHapBsh)]$_2$</td>
<td>-</td>
<td>12.0</td>
<td>6.51-7.72</td>
<td>2.0</td>
</tr>
<tr>
<td>Zn(FHapBsh)$_2$</td>
<td>-</td>
<td>11.68</td>
<td>6.78-7.84</td>
<td>2.2</td>
</tr>
</tbody>
</table>

The $^1$H NMR spectrum shows the $\delta$(-OH) and $\delta$(N-H) groups protons at 11.41 ppm and 11.19 ppm respectively, with integration values corresponding to one proton for each one. A singlet peak which appeared at lower frequency at 2.2 ppm with integration to
three protons was assigned to methyl group (CH₃). The benzene rings protons are appeared in the range of (6.81-7.84 ppm).

**Table 3.16:**

<table>
<thead>
<tr>
<th>Compounds</th>
<th>δ(C=N)</th>
<th>δ(C-O)</th>
<th>δ(Arom.)</th>
<th>δ(CH₃)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FHapBsh</td>
<td>157.82</td>
<td>154.14</td>
<td>114.87-148.28</td>
<td>15.31</td>
</tr>
<tr>
<td>Cd(FHapBsh)₂H₂O</td>
<td>174.95</td>
<td>154.62</td>
<td>111.92-144.57</td>
<td>21.28</td>
</tr>
<tr>
<td>[Ni(FHapBsh)]₂</td>
<td>154.24</td>
<td>144.23</td>
<td>125.42-132.13</td>
<td>13.02</td>
</tr>
<tr>
<td>Zn(FHapBsh)₂</td>
<td>156.51</td>
<td>154.26</td>
<td>114.50-139.69</td>
<td>14.96</td>
</tr>
</tbody>
</table>

The $^{13}\text{C}_{\{^1\text{H}\}}$ NMR spectrum of the ligand (3. 3 ) shows signal due to azomethine carbon (C=N) at 157.82 ppm. The (C-OH) carbon has appeared at 154.14 ppm. The spectrum shows a peak in the region of 114.87-148.28 ppm, due to aromatic carbons. A peak appeared at lower frequency at 15.31 ppm was assigned to methyl group (CH₃).

**IR-spectra of complexes:**

The ligand (3. 3) behaves as a bidentate coordinating to the Cd(II), Cu(II), Ni(II) and Zn(II) ions via the azomethine nitrogen and the phenolic oxygen, supporting by IR spectrum by following evidences. The band of $\nu$(N-H) still appear in the complexes spectrum around wave number 3150 cm⁻¹ indicating that there is no coordination between this nitrogen and the metal atoms. IR frequencies of the ligand and its complexes are listed in Table 3. 14.
Figure 3.20: The IR spectrum of Zn(FHapBsh)$_2$

The band of $\nu$(OH) disappeared in all complexes and $\nu$(C-O) shifts to higher wavenumber from 1075 cm$^{-1}$ to maximum 1126 cm$^{-1}$. The $\nu$(C=N) bands in all complexes has shifted to lower frequency from 1573 cm$^{-1}$ in the free ligand to minimum 1539 cm$^{-1}$ in Cu(II) complex, due to the lowering of the $\nu$(C=N) bond order as a result of M-N bond formation. The shifting of the $\nu$(N-N) to higher wavenumbers further support coordination of the ligand via the azomethine nitrogen atom in forming of the complexes.
Figure 3.21: The IR spectrum of [Cu(FHapBsh)]₂

Figure 3.22: The IR spectrum of [Ni(FHapBsh)]₂

On the other hand the SO₂ bands remain unaltered, indicating that these groups did not take part in coordination. The new bands at lower frequency 400-420 cm⁻¹ and 500 cm⁻¹-525 could be assigned to M-N and M-O respectively. IR spectra for all complexes
showed broad band of H₂O molecules around 3445 cm⁻¹ which was confirmed by thermal analysis located inside the coordination sphere in Cd(II) complex and outside coordination sphere in the others complexes (Abdel-Ghani et al., 1989).

Figure 3.23: The IR spectrum of Cd(FHapBsh)]₂H₂O

**H¹ N.M.R. data of the complexes:**

The 11.41 ppm signal, downfield of TMS, attributed to the proton of OH (phenolic) group in the spectrum of the ligand, is not observed in the spectrum of the Ni(II) and Zn(II) complexes indicating the participation of OH in bonding with displacement of a hydrogen atom. The (N-H) group protons appeared at 12.0 ppm and 11.68 ppm in Ni(II) and Zn(II) complexes respectively. A singlet peak appeared at lower frequency around 2.20 ppm was assigned to methyl group (CH₃). The signals at 6.5-7.80 ppm, was assigned to protons of the phenyl rings of the complexes.

**¹³C{¹H}NMR data of the complexes:**

The ¹³C{¹H}NMR spectra of the complexes show signals due to azomethine carbon (C=N) is observed in the range of 156-175 ppm. The signals due to C-O carbon is
observed in the 144-154.26 ppm. The signals of the carbon atoms of benzene rings are observed approximately in the range of 111.92-144.57 ppm. The signals at around 21.28 ppm was attributed to the methyl carbon. $^{13}$C{H}NMR spectra can’t be obtained in Cu(II) complex indicating that complex is paramagnetic.

Figure 3.24: The $^{13}$C {H} NMR spectrum of Cd(FHapBsh)$_2$H$_2$O

Figure 3.25: The $^{13}$C {H} NMR spectrum of [Ni(FHapBsh)]$_2$
**UV-visible spectral data:**

Table 3.17: Electronic absorption spectra of free ligands and their metal complexes in the UV region:

<table>
<thead>
<tr>
<th>Compound</th>
<th>λ (nm)</th>
<th>M</th>
<th>π ——&gt; π*</th>
<th>n ——&gt; π*</th>
<th>LMCT</th>
<th>d-d</th>
</tr>
</thead>
<tbody>
<tr>
<td>FHapBsh</td>
<td>10⁻³</td>
<td>235,260,280</td>
<td>305,320,330</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>[Cd(FHapBsh)₂H₂O</td>
<td>10⁻³</td>
<td>220,240,270</td>
<td>295,310,325</td>
<td>355,380</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>[Cu(FHapBsh)₂</td>
<td>10⁻³</td>
<td>205,220,240,255</td>
<td>300</td>
<td>350,360</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>[Ni(FHapBsh)₂</td>
<td>10⁻³</td>
<td>230,245,255,265</td>
<td>285,305</td>
<td>365-375</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Zn(FHapBsh)₂</td>
<td>10⁻⁴</td>
<td>215,235,245</td>
<td>300,310,320</td>
<td>345,360</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

The electronic absorption data of the ligand (3. 3) and its complexes were recorded at range 200-800 nm. The weak shoulder band in the 305-400 nm range is assigned to the n ——> π* transition of the azomethine group. The strong intense bands in the 235-280 nm range are attributed to the π ——> π* transition of the azomethine group and benzene ring. On comparing 2-hydroxyl acetophenone complexes with 5’-flouro-2’-hydroxyacetophenone the flouro complexes exhibit λ_max at lower energy regions. This may be due to the deviation of metal ions from their square-basal coordination plane upon halide ion coordination. In the complexes, these bands are shifted to lower wavelengths. In the spectra of the complexes the less intense and broad bands in the 345-400 nm range due to the LMCT(ligand to metal charge transfer bands) transition from the lone pairs of the phenolic oxygen donor to the M(II) ions (Somez et al., 2002). This band more broad in Cu(II) complex. The band at 305-330 nm in the ligand which assigned to the n ——> π* transition of the azomethine group, are shifted, after complexation to
lower wavelengths, in 285-325 nm range suggesting that the nitrogen atom of the azomethine group is coordinated to the metal ion. The other high energy transition observed as strong bands in the range 215-270 nm is assigned to the $\pi \rightarrow \pi^*$ transition of the benzene ring and azomethine group (Sivasankaran et al., 2007). The expected d-d transition in the visible region for complexes of the ligand (3. 3) cannot be detected even with concentrated solution. It may be lost in the low energy tail of the charge transfer transition (Nashar et al., 2004).

**Thermal studies:**

The weight loss was measured from 30 °C up to ≈ 900°C. The weight losses for each chelate were calculated for the corresponding temperature ranges and are shown in Table 3.18. The metal percentages calculated from metal oxide residues were compared with those determined by the analytical metal content determination (Macdonald et al., 1969). The Cd(II) complex (Figure 3.26) was stable up to 37.12°C and its decomposition started at this temperature and completed at 847.15°C. As shown in Table 3.18, a mass loss occurred within the temperature range 37.12-94.06°C corresponding to the loss of hydrated water molecules and at the temperature range 141.04-172.36°C corresponding to a loss of coordinated water molecule. In the temperature range 315.07-397.93°C a mass loss occurred corresponding to a loss of (Ph-SO-NH-N)₂O. At the temperature range 279.13-357.43°C mass losses occurred due to the loss of (C-CH₃)₂. Finally, the loss of (Ph-F)₂ started from 343.19°C to 847.15°C. The decomposition continues till a constant weight is obtained where Ni₂O₃ residue is formed in 24.64%.
Figure 3.26: The TGA spectrum of \([\text{Cd}($FHapBsh$)]_2\text{H}_2\text{O}\)

For Ni(II) complex (Figure 3.27), a mass loss occurred within the temperature range 113.02-165.35°C corresponding to the loss of \([\text{C(CH}_3]_2=\text{N}\] molecules and at the temperature range 166.81-315.07°C corresponding to a loss of (Ph.O)\_2. In the temperature range 315.07-397.93°C a mass loss occurred corresponding to a loss of (NH)\_2O. At the temperature range 400.83-588.34°C the mass losses occurred due to loss of (Ph-F)\_2 and the loss of S\_2O occurred in range 589.80-863.1°C. The decomposition continues till a constant weight is obtained where Ni\_2O residue is formed in 17.45%.
Figure 3.27: The TGA spectrum of [Ni(FHapBsh)]

The Cd(II) complex is thermally stable up to around 37.12 °C. In the TGA curve of this complex, 10.82% weight loss was observed. This shows that the complex contains four water molecules outside the coordination sphere. The second loss of the mass is at 141.04 °C. In the TGA curve shows 2.79% weight loss was observed. This shows that the complex contains 1 mole of water per complex molecule. The IR spectrum of the complex is characterized by the appearance of a broad band around 3445 cm\(^{-1}\), due to the ν (-OH) of the water. This molecule of coordinated water was identified by the elemental analyses confirming the location of water molecules inside the complex structure. The Ni(II) complex is thermally stable up to around 113.02 °C as it can be seen in Table 3.18 so the Ni(II) complex is more stable than Cd(II) complex.
Table 3.18:
TGA data of the [Cd(FHapBsh)]$_2$H$_2$O and [Ni(FHapBsh)]$_2$:

<table>
<thead>
<tr>
<th>Complex</th>
<th>Step</th>
<th>Temperature ($^\circ$C)</th>
<th>Weight loss (%) Found(Calculated)</th>
<th>Assignment</th>
<th>Residue (%) Found(Calculated)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cd(II)</td>
<td>1</td>
<td>37.12-94.06</td>
<td>10.82(9.69)</td>
<td>4H$_2$O</td>
<td>Cd$_2$O</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>141.04-172.36</td>
<td>2.79(2.11)</td>
<td>H$_2$O</td>
<td>27.95(28.17)</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>173.78-277.71</td>
<td>40.42(41.21)</td>
<td>(Ph-SO-NH-N)$_2$O</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>279.13-357.43</td>
<td>7.03(6.32)</td>
<td>(C-CH$_3$)$_2$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>343.19-847.15</td>
<td>21.81(21.98)</td>
<td>(Ph-F)$_2$</td>
<td></td>
</tr>
<tr>
<td>Ni(II)</td>
<td>1</td>
<td>113.02-165.35</td>
<td>10.61(11.24)</td>
<td>[C(CH$_3$)=N]$_2$</td>
<td>Ni$_2$O</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>166.81-315.07</td>
<td>28.533(25.50)</td>
<td>(Ph.O)$_2$</td>
<td>17.45(18.28)</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>315.07-397.93</td>
<td>5.49(6.03)</td>
<td>N$_2$O</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>400.83-588.34</td>
<td>25.03(25.77)</td>
<td>(Ph-F)$_2$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>589.80-863.1</td>
<td>12.89(10.96)</td>
<td>S$_2$O</td>
<td></td>
</tr>
</tbody>
</table>

Proposed structures of the (FHapBsh) complexes:

\[ M=\text{Cd(II)} \]
According to thermal analysis, there are two metal atoms in the complex molecule, leading to the previous structure. The elemental analysis data was in good agreement with the proposed structure of the complexes. This feature is in contrast with a study about Ni(II) complexes was done by (Mishtu et al., 2002), wherein the di-nuclear complexes involve bridging of the phenoxy group.
3. 4- 2'- (5-Bromo -2-hydroxybenzylidene)benzenesulfanohydrazide

The ligand (3. 4) was prepared by acidified ethanol solution of Benzenesulfanohydrazide with 5'-bromo -2'-hydroxyacetophenone (1:1). All the complexes of this ligand were prepared by mixing basified solution of the ligand and metal (II) acetate (2:1). Table 3.19 shows the elemental analytical data for the ligand and its complexes agree with the theoretical data.

Table 3.19:
Elemental analytical results of the ligand and its Cd(II), Cu(II), Ni(II) and Zn(II) complexes:

<table>
<thead>
<tr>
<th>Compound</th>
<th>Calculated (found)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>C%</td>
</tr>
<tr>
<td>BrHapBsh</td>
<td>45.49(45.81)</td>
</tr>
<tr>
<td>Cd( BrHapBsh)₂</td>
<td>39.71(39.76)</td>
</tr>
<tr>
<td>[Cu(BrHapBsh)]₂(DMSO)₂</td>
<td>37.86(38.45)</td>
</tr>
<tr>
<td>[Ni(BrHapBsh)]₂</td>
<td>39.50(40.75)</td>
</tr>
<tr>
<td>[Zn(BrHapBsh)]₂H₂O</td>
<td>38.12(39.72)</td>
</tr>
</tbody>
</table>
### Table 3.20:
IR- spectra of the ligand and its Cd(II), Cu(II), Zn(II) and Ni(II) complexes:

<table>
<thead>
<tr>
<th>Compounds</th>
<th>$\nu$(Ar-OH)</th>
<th>$\nu$(N-H)</th>
<th>$\nu$(C=N)</th>
<th>$\nu$(S=O)</th>
<th>$\nu$(C-O)</th>
<th>$\nu$(N-N)</th>
<th>$\nu$(M-O)</th>
<th>$\nu$(M-N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BrHapBsh</td>
<td>3423</td>
<td>3232</td>
<td>1609</td>
<td>1321, 1158</td>
<td>1074</td>
<td>1019</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Cd(BrHapBsh)$_2$</td>
<td>-</td>
<td>3232</td>
<td>1561</td>
<td>1321, 1158</td>
<td>1091</td>
<td>1023</td>
<td>514</td>
<td>420</td>
</tr>
<tr>
<td>[Cu(BrHapBsh)]$_2$ (DMSO)$_2$</td>
<td>-</td>
<td>-</td>
<td>1579</td>
<td>1321, 1158</td>
<td>1090</td>
<td>1037</td>
<td>574</td>
<td>455</td>
</tr>
<tr>
<td>[Zn(BrHapBsh)]$_2$ H$_2$O</td>
<td>-</td>
<td>3232</td>
<td>1601</td>
<td>1322, 1158</td>
<td>1080</td>
<td>1021</td>
<td>577</td>
<td>497</td>
</tr>
<tr>
<td>[Ni(BrHapBsh)]$_2$</td>
<td>-</td>
<td>3231</td>
<td>1561</td>
<td>1321, 1158</td>
<td>1081</td>
<td>1024</td>
<td>514</td>
<td>441</td>
</tr>
</tbody>
</table>

**IR-spectrum of ligand:**

As expected, the IR data was consistent with that reported for the previous ligands, in which azomethine group $\nu$(C=N) occurred at 1609 cm$^{-1}$. The $\nu$(N-H) stretching appeared at wavenumber 3232 cm$^{-1}$. The $\nu$(OH) band observed at 3423 cm$^{-1}$, which was at lower wavenumber with respect to the free OH group (3700-3500 cm$^{-1}$) due to intramolecular hydrogen bonding as will be discussed later through x-ray structure. They are two bands of $\nu$(S=O) groups appeared at 1158 cm$^{-1}$ and 1321 cm$^{-1}$ (Figure 3.28 shows the IR spectrum of the ligand 3.4).
Figure 3.28: The IR spectrum of BrHapBsh

NMR spectrum data of the ligand:

Table 3.21:
$^1$H NMR data of the ligand and its Ni(II) complex:

<table>
<thead>
<tr>
<th>Compounds</th>
<th>$\delta$(OH)</th>
<th>$\delta$(NH)</th>
<th>$\delta$(Arom.)</th>
<th>$\delta$(CH3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BrHapBsh</td>
<td>11.65</td>
<td>10.42</td>
<td>6.80-8.117</td>
<td>2.49</td>
</tr>
<tr>
<td>$[\text{Ni(BrHapBsh)}]_2$</td>
<td>-</td>
<td>12.96</td>
<td>6.70-7.78</td>
<td>2.17</td>
</tr>
</tbody>
</table>

The $^1$H NMR spectrum shows the $\delta$(-OH) and $\delta$(N-H) groups protons at 11.65 ppm and 10.42 ppm respectively, with integration values corresponding to one proton for each one. The benzene rings protons are appeared in range of (6.80-8.12 ppm).
Table 3.22:
\(^{13}\text{C}\{^{1}\text{H}\}\text{NMR data of the ligand and its Cd(II) and Ni(II) complexes:}\)

<table>
<thead>
<tr>
<th>Compounds</th>
<th>(\delta) (C=N)</th>
<th>(\delta) (C-O)</th>
<th>(\delta) (Arom.)</th>
<th>(\delta) (CH\text{3})</th>
</tr>
</thead>
<tbody>
<tr>
<td>BrHapBsh</td>
<td>155.56</td>
<td>143.57</td>
<td>110.59-138.79</td>
<td>13.0</td>
</tr>
<tr>
<td>Cd(BrHapBsh)_2</td>
<td>157.76</td>
<td>145.83</td>
<td>109.14-130.24</td>
<td>12.27</td>
</tr>
<tr>
<td>[Ni(BrHapBsh)]_2</td>
<td>156.89</td>
<td>141.82</td>
<td>104.30-131.62</td>
<td>13.33</td>
</tr>
</tbody>
</table>

The \(^{13}\text{C}\) NMR spectrum of the ligand (BrHapBsh) shows signals due to azomethine carbon (C=N) is observed in the 143.57 ppm. The \(\delta\) (C-OH) carbon has appeared at 155.56 ppm. The spectrum shows peaks in the region of 110.6-138.79 ppm, due to aromatic carbons.

**x-ray data of the ligand:**

Figure 3. 29 is an ORTEP diagram showing the structure of the molecule of the ligand. The two symmetry-independent molecules of the title compound, are linked by N—H---Os (s =sulfonyl) and N—H----OH hydrogen bonds to furnish a chain that propagates along the a axis of the monoclinic unit cell. The asymmetric unit in the crystal structure of 2’-[1-(5-chloro-2-hydroxyphenyl)ethylidene]benzenesulfonohydrazide, (II), contains two molecules that are linked by an N—H----Os (s =sulfonyl) hydrogen bond [N----O = 2.929 (2)\(\text{Å}\)] to form a dimer (Ali et al., 2007). The compound, (Fig. 3. 23), has a Br atom in place of a chloro atom. It also lacks the methyl group attached to the C atom of the C= N linker in (II) (Ali et al., 2007). The absence of the methyl group on this linkage allows the two independent molecules to connect into a chain through hydrogen bonds (Hapipah M., Musalem Laila et al, 2007).
Figure 3.29:
The structure of the two independent molecules of (3. 4). H atoms are shown as spheres of arbitrary radius. Intramolecular hydrogen bonds are shown dashed.

One –NH donor site interacts with the sulfanyl acceptor site whereas the other –NH donor site interacts with the hydroxyl acceptor site. The hydrogen-bonded chain propagates along the an axis. An intramolecular O—H-----N hydrogen bond occurs in both molecules.

IR-spectra of complexes:
IR spectrum data of Cd(II), Ni(II) and Zn(II) complexes (Table 3. 20) showed a broad band of H$_2$O molecules at 3446-3448 cm$^{-1}$ which was confirmed by thermal analysis located outside the coordination sphere in Cd(II) (Figure 3. 32) and Ni(II) (Figure 3. 30) complexes and inside coordination sphere in Zn(II) complex (Figure 3. 33). In all complexes spectra of this ligand, the band of $\nu$(OH) at 3423cm$^{-1}$ in the free ligand disappeared. In the same time, phenolic C-O of the of the free ligands is observed at 1074 cm$^{-1}$. Upon chelation, this band was shifted to higher wave number 1080-1091 cm$^{-1}$ which means that the shift is due to coordination of ligand to metal atom by the phenolic oxygen (Canfolat et al., 2005).
Figure 3.30: The IR spectrum of [Ni(BrHapBsh)]$_2$

Also in all complexes spectra, the $\nu$(C=N) band at 1609 cm$^{-1}$ is shifted to the lower wave number denoting that nitrogen atom of the azomethine group is coordinated to the M(II) ion. The shifting of the $\nu$(N-N) to higher wavenumbers from 1019 cm$^{-1}$ for the ligand to maximum 1037 cm$^{-1}$ in all complexes also support coordination of the ligand via the azomethine nitrogen atom. $\nu$(N-H) band at 3232 cm$^{-1}$ in the the free ligand disappeared after complexation to form Cu(II) complex (Figure 3.31) because of the coordination of the ligand to the metal center via nitrogen atom.
Figure 3.31: The IR spectrum of $[\text{Cu(BrHapBsh)]_2(DMSO)}_2$

The x-ray ORTEP shows that there are two DMSO molecules binding to Cu(II) atom after recrystallization (Figure 3.36). The bonding of the metal (II) ions to the ligand through the nitrogen and oxygen atom to form the complexes is further supported by the presence of new bands in 514-577 cm$^{-1}$ and 420-497 due to the $\nu$(M-O) and $\nu$(M-N) respectively. On the other hand the SO$_2$ bands at 1321 cm$^{-1}$ and 1158 cm$^{-1}$ remain unaltered, indicating that these groups did not take part in coordination.
Figure 3.32: The IR spectrum of \( \text{Cd(BrBapBsh)}_2 \)

Figure 3.33: The IR spectrum of \([\text{Zn(BrBapBsh)}]_2\text{H}_2\text{O}\)
H¹ N.M.R. data of the complexes:
The ¹H NMR spectrum (Figure 3.34) gives useful in establishing the nature and structure of Ni(II) complex. The data clearly indicated the (N-H) group proton at 12.96 ppm. The complex spectrum shows that δ(OH) phenolic peak at 11.65 ppm in the ligand has disappeared indicating coordination of this groups to metal center. A singlet peak appeared at lower frequency at 2.17 ppm with integration to three protons was assigned to methyl group (CH₃). The signals at 6.70-7.78 ppm could be assigned to the protons of the phenyl rings (Table 3.21).

Figure 3.34: The ¹H NMR spectrum of [Ni(BrHapBsh)]₂

¹³C{¹H}NMR data of the complexes:
The ¹³C{¹H}NMR spectrum of the Cd(II) and Ni(II) complexes (Table 3.22) show signal due to azomethine carbon (C=N) is observed in the 157.76 ppm and 156.89 ppm
respectively. The signals due to C-O carbon is observed in the range of 141.82-145.83 ppm. The signals of the carbon atoms of the benzene rings are observed approximately in the range 109.14-131.62 ppm. The signal in the range of 12.27-13.33 ppm can be attributed to the methyl carbon. The \(^1\)H and \(^{13}\)C\{\(^1\)H\}NMR spectra can not be obtained in Cu(II) and Zn(II) complex indicating that complexes are paramagnetic.

![Figure 3.35: The \(^{13}\)C\{\(^1\)H\}NMR spectrum of \([\text{Ni(BrHapBsh)}]_2\)](image)

**X-ray data of \([\text{Cu(BrHapBsh)}]_2\)\((\text{DMSO})_2\) complex:**

In the structure of the molecule, as shown in Figure 3.36, Centro symmetric dinuclear complex, \([\text{Cu}_2(\text{C}_{15}\text{H}_{11}\text{BrN}_2\text{O}_3\text{S})_2(\text{C}_2\text{H}_6\text{OS})_2]\), the Cu(II) ion is N,O chelated by a dianionic ligand, monocoordinated by the sulfonamide N atom of a symmetry-related ligand and coordinated by an oxygen atom from a dimethyl sulfoxide ligand, forming a distorted square-planar coordination geometry (Hapipah et al., 2008). The size of the solvent can play an important role in the structure of the complexes. DMSO is smaller
size than pyridine, gave dimmer complex. While the same complex with pyridine has monomeric complex. (Hapipah et al., 2006)

Figure 3.36:
The structure of the symmetric dinuclear Cu(II) complex of [BrHapBsh]

UV-visible spectral data:

Table 3.23:
Electronic absorption spectra of free ligands and their metal complexes in the UV region

<table>
<thead>
<tr>
<th>Compound</th>
<th>λ (nm)</th>
<th>M</th>
<th>π → π*</th>
<th>n → π*</th>
<th>LMCT</th>
<th>d-d</th>
</tr>
</thead>
<tbody>
<tr>
<td>BrHapBsh</td>
<td>10⁻³</td>
<td>220,230,250</td>
<td>320</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Cd(BrHapBsh)₂</td>
<td>10⁻⁴</td>
<td>205,215,225,240</td>
<td>255,270,325</td>
<td>360,370</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>[Cu(BrHapBsh)]₂(DMSO)₂</td>
<td>10⁻³</td>
<td>205,225</td>
<td>270,290,300</td>
<td>365,380</td>
<td>675</td>
<td></td>
</tr>
<tr>
<td>[Ni(BrHapBsh)]₂</td>
<td>10⁻⁴</td>
<td>205,220,240</td>
<td>255,270,280,325</td>
<td>335,370</td>
<td>670</td>
<td></td>
</tr>
<tr>
<td>[Zn(BrHapBsh)]₂(H₂O)</td>
<td>10⁻⁴</td>
<td>210,220,230</td>
<td>260,305,325</td>
<td>335-360</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>
The UV-visible data of the ligand (BrHapBsh) and its complexes were recorded in 200-800 nm. The weak bands in 220-250 nm range which assigned to the $\pi \rightarrow \pi^*$ transition involves molecular orbitals essentially localized on C=N group and phenyl ring. The weak band as shoulder at 320 nm is assigned to $n \rightarrow \pi^*$ transition involving molecular orbitals of the azomethine group chromophore. On comparing 2-hydroxyl acetophenone complexes with 5’-bromo-2’-hydroxyacetophenone the bromo complexes exhibit $\lambda_{\text{max}}$ at lower energy regions. This may be due to the deviation of metal ions from their square-basal coordination plane upon halide ion coordination. By comparing of the electronic absorption spectra of the free ligand and its complexes, It is observed that the bands appearing in range of 205-240 nm slightly decreases in intensity in Ni(II) and Cd(II) complexes. These bands may attributed to $\pi \rightarrow \pi^*$ transition of the phenyl ring and shift to lower energy in all complexes. The spectra of the all complexes of the ligand (3. 4) show low intensity bands at range 335-675 nm due to d-d transition of the metal ion and LMCT (ligand to metal charge transfer bands) transition from the lone pairs of the phenolic oxygen donor to the M(II) ions. Bands in range 255-325 nm are assigned to $n \rightarrow \pi^*$ transition involving molecular orbitals of the azomethine group chromophore. These bands have lower wavenumbers as a result to the coordination between the ligand and the metal ion. The $\pi \rightarrow \pi^*$ transition due to the aromatic ring chromophore shifted upon coordination to higher energy in range 205-240 nm. The Cu(II) complex has larger red shifted than other complexes comparing to the ligand (3. 4).
Thermal studies:

Thermal stability of the complexes was investigated using TGA. TGA curves were obtained at heating under N₂ atmosphere at a heating rate of 10 °C/min. In temperature range of 30-900 °C.

The Cd(II) complex (Figure 3.37) was stable up to 31.82 °C and its decomposition started at this temperature and was completed at 599.79 °C. A mass loss occurred within the temperature range 31.82-62.17 °C corresponding to the loss of hydrated water molecules.

In the temperature range 63.70-132.62 °C a mass loss occurred corresponding to a loss of Ph.O₂. At the temperature range 132.62-279.67 °C mass losses occurred due to the loss of Ph-Br.(SO). The fifth step occurred at 279.67-327.15 °C corresponding to a loss of (N-NH)₂. The remaining intermediate contains Ph- and Ph-Br. (C-CH₃)₂, are eliminated in two steps, 279.67-327.15 °C and 380.76-599.79 °C respectively. The decomposition process continues till a constant weight is obtained where CdO₂ residue is formed by 18.56%.

Figure 3.37: The TGA spectrum of Cd (BrHapBsh)₂
The Ni(II) complex (Figure 3.38) was stable up to 47.29 °C and its decomposition started at this temperature and was completed at 798.12 °C. A mass loss occurred within the temperature range 47.29-142.41°C corresponding to the loss of non coordinated water molecules. In the temperature range 143.85-290.84 °C a mass loss occurred corresponding to a loss of (Ph-SO₂-NH-N=C-CH₃)₂. At the temperature range 292.28-638.15 °C mass losses occurred due to the loss of (Ph-Br).Br. The final step occurred at 639.60-798.12 °C corresponding to a loss of (Ph)₂. The decomposition process continues till a constant weight is obtained where Ni₂O residue is formed by 13.20%.

**Figure 3.38:** The TGA spectrum of [Ni(BrHapBsh)]₂

For Zn(II) complex (Figure 3.39), a mass loss occurred within the temperature range 50.12-87.68°C corresponding to the loss of hydrated water molecules and at the temperature range 89.02-153.41°C corresponding to a loss of coordinated water molecule. In the temperature range 153.41-286.22 °C a mass loss occurred corresponding to a loss of Ph-(SO)₂N-N.O.Ph-Br. At the temperature range 287.56-314.39 °C the mass
losses occurred due to loss of C-CH$_3$ and the loss of C-(CH$_3$)N-N started from 313.05 to 370.73 °C. The loss of Ph-O and Ph-Br started from 372.07 °C to 795.98 °C. The decomposition continues till a constant weight is obtained where Zn$_2$O$_2$ residue is formed in 20.72%.

Figure 3.39: The TGA spectrum of [Zn(BrHapBsh)]$_2$H$_2$O

The Cd(II), Zn(II) and Ni(II) complexes are thermally stable up to around 30-50 °C. In the TGA curves of these complexes, 5.86%, 1.39% and 5.5% weight loss was observed. This shows that the complexes contain 2 moles, 1 mole and 2 moles of non coordinated water per complex molecule respectively. The IR spectrum of the complexes is characterized by the appearance of a broad band in the region 3440-3450 cm$^{-1}$, due to the $\nu$ (-OH) of the water. This water was not identified by the elemental analyses confirming the location of water molecules outside the complex structure, while in Zn(II) a molecule of coordinated water was detected by elemental analyses. Table 3.24 shows the TGA data of Cd(II), Zn(II) and Ni(II) complexes.
Table 3.24:
TGA data of the Cd (BrHapBsh)$_2$, [Zn(BrHapBsh)]$_2$H$_2$O and [Ni(BrHapBsh)]$_2$:

<table>
<thead>
<tr>
<th>Complex</th>
<th>Step</th>
<th>Temperature (°C)</th>
<th>Weight loss (%) Found(Calculated)</th>
<th>Assignment</th>
<th>Residue (%) Found(Calculated)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cd(II)</td>
<td>1</td>
<td>31.82-62.17</td>
<td>5.86(4.25)</td>
<td>2H$_2$O</td>
<td>CdO$_2$</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>63.70-132.62</td>
<td>10.87(12.88)</td>
<td>Ph.O$_2$</td>
<td>18.56(17.06)</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>132.62-279.67</td>
<td>30.39(29.77)</td>
<td>Ph-Br.(SO)$_2$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>279.67-327.15</td>
<td>6.80(6.85)</td>
<td>(N-NH)$_2$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>327.15-382.29</td>
<td>8.35(9.09)</td>
<td>Ph-</td>
<td></td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>380.76-599.79</td>
<td>25.03(24.81)</td>
<td>Ph-Br.(C-CH$_3$)$_2$</td>
<td></td>
</tr>
<tr>
<td>Zn(II)</td>
<td>1</td>
<td>50.12-87.68</td>
<td>1.39(2.03)</td>
<td>H$_2$O</td>
<td>Zn$_2$O$_2$</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>89.02-153.41</td>
<td>1.00(2.03)</td>
<td>H$_2$O</td>
<td>20.72(18.35)</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>153.41-286.22</td>
<td>42.16(42.07)</td>
<td>Ph-(SO)$_2$N-N.O.Ph-Br</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>287.56-314.39</td>
<td>2.51(3.04)</td>
<td>C-CH$_3$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>313.05-370.73</td>
<td>4.71(6.20)</td>
<td>C-(CH$_3$)N-N</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>372.07-541.10</td>
<td>11.87(10.48)</td>
<td>Ph-O</td>
<td></td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>542.44-795.98</td>
<td>17.03(17.59)</td>
<td>Ph-Br</td>
<td></td>
</tr>
<tr>
<td>Ni(II)</td>
<td>1</td>
<td>47.29-142.41</td>
<td>5.5(4.21)</td>
<td>2H$_2$O</td>
<td>Ni$_2$O</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>143.85-290.84</td>
<td>45.60(45.84)</td>
<td>(Ph-SO$_2$-NH-N=C-CH$_3$)$_2$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>292.28-638.15</td>
<td>28.5(29.3)</td>
<td>(Ph-Br).Br</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>639.60-798.12</td>
<td>12.7(9.0)</td>
<td>Ph</td>
<td></td>
</tr>
</tbody>
</table>
Proposed structures of the (BrHapBsh) complexes:

\[ \text{M=Cd(Ii)} \]

\[ \text{M= Ni(Ii)} \]
According to thermal analysis, there are two metal atoms in the complex molecule, leading to the previous structure. The elemental analysis data was in good agreement with the proposed structure of the complexes. This feature is in contrast with a study about Ni(II) complexes was done by (Mishtu et al., 2002), wherein the di-nuclear complexes involve bridging of the phenoxy group.
3. 5- 2’- (5-Methyl -2-hydroxybenzylidene)benzenesulfanohydrazide

The ligand (3. 5) was prepared by acidified ethanol solution of benzenesulfanohydrazide with 2’-hydroxy 5’-methyl -acetophenone (1:1). All the complexes of this ligand were prepared by mixing basified solution of the ligand and metal (II) acetate (2:1). Table 3.25 shows the elemental analytical data for the ligand and its complexes agree with the theoretical data.

**Table 3. 25:**
Elemental analytical results of the ligand and its Cd(II), Cu(II), Ni(II) and Zn(II) complexes :

<table>
<thead>
<tr>
<th>Compound</th>
<th>Calculated (found)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>C%</td>
</tr>
<tr>
<td></td>
<td>H%</td>
</tr>
<tr>
<td></td>
<td>N%</td>
</tr>
<tr>
<td>methHapBsh</td>
<td>59.13(59.19)</td>
</tr>
<tr>
<td></td>
<td>5.25(5.60)</td>
</tr>
<tr>
<td></td>
<td>9.19(9.26)</td>
</tr>
<tr>
<td>Cd(methHapBsh)$_2$</td>
<td>50.11(51.99)</td>
</tr>
<tr>
<td></td>
<td>4.18(4.77)</td>
</tr>
<tr>
<td></td>
<td>7.79(7.99)</td>
</tr>
<tr>
<td>[Cu(methHapBsh)]$_2$</td>
<td>49.11(48.59)</td>
</tr>
<tr>
<td></td>
<td>4.09(3.70)</td>
</tr>
<tr>
<td></td>
<td>7.64(7.40)</td>
</tr>
<tr>
<td>[Ni(methHapBsh)]$_2$(H$_2$O)$_2$</td>
<td>47.43(48.59)</td>
</tr>
<tr>
<td></td>
<td>4.48(3.70)</td>
</tr>
<tr>
<td></td>
<td>7.38(7.41)</td>
</tr>
<tr>
<td>[Zn(methHapBsh)]$_2$H$_2$O</td>
<td>52.22(53.22)</td>
</tr>
<tr>
<td></td>
<td>4.64(5.07)</td>
</tr>
<tr>
<td></td>
<td>8.12(8.03)</td>
</tr>
</tbody>
</table>
### Table 3.26:
IR- spectra of the ligand and its Cd(II), Cu(II), Zn(II) and Ni(II) complexes:

<table>
<thead>
<tr>
<th>Compounds</th>
<th>( v(\text{Ar-OH}) )</th>
<th>( v(\text{N-H}) )</th>
<th>( v(\text{C=\text{N}}) )</th>
<th>( v(\text{S=O}) )</th>
<th>( v(\text{C-O}) )</th>
<th>( v(\text{N-N}) )</th>
<th>( v(\text{M-O}) )</th>
<th>( v(\text{M-N}) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>methHapBsh</td>
<td>3382</td>
<td>3242</td>
<td>1609</td>
<td>1323, 1169</td>
<td>1083</td>
<td>1042</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Cd(methHapBsh)_2</td>
<td>-</td>
<td>3242</td>
<td>1561</td>
<td>1323, 1171</td>
<td>1129</td>
<td>1070</td>
<td>557</td>
<td>409</td>
</tr>
<tr>
<td>[Cu(methHapBsh)]_2</td>
<td>-</td>
<td>3448</td>
<td>1579</td>
<td>1286, 1151</td>
<td>1136</td>
<td>1049</td>
<td>581</td>
<td>498</td>
</tr>
<tr>
<td>[Ni(methHapBsh)]_2(H_2O)_2</td>
<td>-</td>
<td>3173</td>
<td>1560</td>
<td>1323, 1163</td>
<td>1131</td>
<td>1072</td>
<td>568</td>
<td>418</td>
</tr>
<tr>
<td>[Zn(methHapBsh)]_2H_2O</td>
<td>-</td>
<td>3242</td>
<td>1584</td>
<td>1323, 1169</td>
<td>1132</td>
<td>1071</td>
<td>557</td>
<td>468</td>
</tr>
</tbody>
</table>

**IR-spectrum of ligand:**

IR spectrum in Figure 3. 40 shows broad band at 3382 cm\(^{-1}\) assignable to \( \nu(\text{OH}) \) phenolic and strong bands in range 3209 cm\(^{-1}\)-3242 cm\(^{-1}\)assignable to \( \nu(\text{N-H}) \) respectively. The lower wavenumber of \( \nu(\text{Ph-OH}) \) band with respect to the free OH group (3700-3500 cm\(^{-1}\)) indicating that the OH involved in the formation of strong intramolecular hydrogen bond. A strong band in the range of 2901-2976 cm\(^{-1}\) assignable to stretching (sp\(^3\)-CH\(_3\)). Strong band of azomethine group (C=\text{N}) occurred at 1609 cm\(^{-1}\). There are two bands at 1323 cm\(^{-1}\) and 1169 cm\(^{-1}\) assigned to two (S=O) groups.
**Figure 3.40:** The IR spectrum of methHapBsh

**NMR spectrum data of the ligand:**

**Table 3.27:**
$^1$H NMR data of the ligand and its Cd(II), Cu(II), Ni(II) and Zn(II) complexes:

<table>
<thead>
<tr>
<th>Compounds</th>
<th>$\delta$(OH)</th>
<th>$\delta$(NH)</th>
<th>$\delta$(Arom.)</th>
<th>$\delta$(CH3)</th>
<th>$\delta$(Ar-CH3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>methHapBsh</td>
<td>11.35</td>
<td>11.02</td>
<td>6.69-7.89</td>
<td>2.26</td>
<td>2.19</td>
</tr>
<tr>
<td>Cd(methHapBsh)$_2$</td>
<td>-</td>
<td>12.97</td>
<td>6.59-7.76</td>
<td>2.48</td>
<td>1.87</td>
</tr>
<tr>
<td>[Cu(methHapBsh)]$_2$</td>
<td>-</td>
<td>11.35</td>
<td>5.79-8.38</td>
<td>2.49</td>
<td>2.17</td>
</tr>
<tr>
<td>[Ni(methHapBsh)]$_2$(H$_2$O)$_2$</td>
<td>-</td>
<td>12.49</td>
<td>6.60-7.76</td>
<td>2.26</td>
<td>2.17</td>
</tr>
<tr>
<td>[Zn(methHapBsh)]$_2$H$_2$O</td>
<td>-</td>
<td>11.9</td>
<td>6.68-7.86</td>
<td>2.30</td>
<td>1.89</td>
</tr>
</tbody>
</table>
The $^1$H NMR spectrum (Figure 3.41) shows the $\delta$(OH) and $\delta$(N-H) groups protons at 11.35 ppm and 11.02 ppm respectively, with integration values corresponding to one proton for each one. A singlet peak appeared at lower frequency at 2.26 ppm with integration to three protons was assigned to methyl group (CH$_3$). The signal of $\delta$(Ar-CH$_3$) has appeared at lower frequency at 2.19 ppm (Pavia et al., 2001). The benzene rings protons appeared in range of (6.70-7.90 ppm).

Figure 3.41: The $^1$H NMR spectrum of methHapBsh
Table 3.28:
$^{13}$C{$_1^H$}NMR data of the ligand and its Cd(II), Cu(II), Ni(II) and Zn(II) complexes:

<table>
<thead>
<tr>
<th>Compounds</th>
<th>$\delta$(C=N)</th>
<th>$\delta$(Arom.)</th>
<th>$\delta$(CH3)</th>
<th>$\delta$(Ar-CH3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>methHapBsh</td>
<td>158.81</td>
<td>116.75-138.13</td>
<td>20.12</td>
<td>14.61</td>
</tr>
<tr>
<td>Cd(methHapBsh)$_2$</td>
<td>155.67</td>
<td>116.08-130.93</td>
<td>20.33</td>
<td>12.83</td>
</tr>
<tr>
<td>[Cu(methHapBsh)]$_2$</td>
<td>145.43</td>
<td>106.73-123.45</td>
<td>10.25</td>
<td>4.71</td>
</tr>
<tr>
<td>[Ni(methHapBsh)]$_2$(H$_2$O)$_2$</td>
<td>155.44</td>
<td>116.12-131.45</td>
<td>20.18</td>
<td>13.17</td>
</tr>
<tr>
<td>[Zn(methHapBsh)]$_2$H$_2$O</td>
<td>155.43</td>
<td>116.50-139.96</td>
<td>20.18</td>
<td>13.99</td>
</tr>
</tbody>
</table>

The $^{13}$C{$_1^H$}NMR spectrum of the ligand 2’-(5-Methyl -2-hydroxybenzylidene)-benzenesulfanohydrazide (Figure 3.42) shows signals due to azomethine carbon (C=N) is observed in the 158.81 ppm. The $\delta$(C-OH) carbon has appeared at 155.34 ppm. The spectrum shows a peak in the region 116.75-138.13 ppm, due to aromatic carbons. The signals at the 20.12 ppm and 14.61 ppm can be attributed to the $\delta$(CH$_3$) and $\delta$(Ar-CH$_3$) carbon atoms respectively.
Figure 3.42: The $^{13}\text{C}\{^1\text{H}\}$NMR spectrum of methHapBsh

X-ray data of the ligand:

According to x-ray structure shown in (Figure 3.43), the two independent molecules in the asymmetric unit of the 2'-(5-Methyl-2-hydroxybenzylidene)benzenesulfanohydrazide are each linked by an N-H---O$_{\text{sulfonyl}}$ hydrogen bond into a linear chain that runs along the shortest axis of the triclinic unit cell. The hydroxyl groups are engaged in intramolecular hydrogen bonding and the amino N atom shows pyramidal coordination (Laila et al., 2008).
**Figure 3.43:**
The structure of the asymmetric unit of methHapBsh. Dashed line indicates H-bonding

**IR-spectra of complexes:**

IR spectra of Ni(II) and Zn(II) complexes (Figure 3. 46 and Figure 3. 47 respectively), show a broad band of H$_2$O molecules in range of 3400- 3447 cm$^{-1}$ that is according to elemental analysis and thermal analysis located inside the coordination sphere. Also IR spectrum of Cd(II) complex (Figure 3. 44 ), shows a broad band of H$_2$O molecules at 3400 cm$^{-1}$ that is according to elemental analysis and thermal analysis located outside the coordination sphere. In all complexes spectra of this ligand, the band of $\nu$ (OH) at 3382 cm$^{-1}$ in the free ligand disappeared. In the same time, phenolic C-O of the of the free ligands is observed at 1083 cm$^{-1}$. Upon chelation, this band was shifted to higher wave number 1129-1136 cm$^{-1}$ which means that the shift is due to coordination of ligand to metal atom by the phenolic oxygen (*Canfolat et al., 2005*).
Figure 3.44: The IR spectrum of Cd(methHapBsh)$_2$

Also in all complexes spectra, the $\nu$(C=N) band at 1609 cm$^{-1}$ shifted to the lower wave number in the range of 1560-1584 cm$^{-1}$, denoting that nitrogen atom of the azomethine group is coordinated to the M(II) ion. The shifting of the $\nu$ (N-N) to higher wavenumbers from 1042 cm$^{-1}$ for the ligand to maximum 1072 cm$^{-1}$ in all complexes also support coordination of the ligand via the azomethine nitrogen atom. $\nu$(N-H) band at 3242 cm$^{-1}$ in the free ligand still appeared after complexation to form Cd(II), Ni(II) and Zn(II) complexes, indicating this group did not take part in coordination to the metal centers as shown in Figures 3.44, 3.46 and 3.47 respectively. $\nu$(N-H) band in Cu(II) complex spectrum buried with the OH band of the water molecule (Figure 3.45). The bonding of the metal (II) ions to the ligand through the nitrogen and oxygen atom to form the complexes is further supported by the presence of new bands in 557-581 cm$^{-1}$ and 409-498 ranges due to the $\nu$(M-O) and $\nu$(M-N) respectively.
Figure 3.45: The IR spectrum of $[\text{Cu} \text{(methHapBsh)}]_2$

Figure 3.46: The IR spectrum of $[\text{Ni} \text{(methHapBsh)}]_2(\text{H}_2\text{O})_2$
**Figure 3.47:** The IR spectrum of $[\text{Zn(methHapBsh)}]_2\text{H}_2\text{O}$

**$^1\text{H}$ N.M.R. data of the complexes:**

The complexes spectra show that $\delta$(OH) phenolic peak at 11.35 ppm in the ligand has disappeared indicating coordination of this group to metal center. The data clearly indicated the $\delta$(N-H) group proton at 11.02 ppm in the ligand still appeared in all complexes in range of 11.02-12.97 ppm, indicating that this group did not take part in coordination. A singlet peaks in the spectra of the complexes appeared in range of 2.26-2.49 ppm with integration to three protons was assigned to methyl group $\delta$(CH$_3$). $\delta$(Ar-CH$_3$) has appeared at lower frequency in range of 1.87-2.17 ppm (*Pavia et al., 2001*). The benzene rings protons appeared in range of 5.79-8.38 ppm.
Figure 3.48: The $^1$H NMR spectrum of Cd(methHapBsh)$_2$

Figure 3.49: The $^1$H NMR spectrum of [Ni(methHapBsh)]$_2$(H$_2$O)$_2$
$^{13}\text{C}^{1\text{H}}\text{NMR data of the complexes:}$

The $^{13}\text{C}^{1\text{H}}\text{NMR}$ spectra of the complexes (Figure 3.50, Figure 3.51 and Figure 3.52) show signals due to azomethine carbon $\delta(C=N)$ is observed in the range of 145.34 - 155.67 ppm. The signals of the carbon atoms of the benzene rings are observed approximately in the range of 106.73-139.96 ppm. The signals at the ranges of 10.25-20.33 ppm and 4.71-13.99 ppm can be attributed to the $\delta(\text{CH}_3)$ and $\delta(\text{Ar-CH}_3)$ carbon atoms respectively.

**Figure 3.50:** The $^{13}\text{C}^{1\text{H}}\text{NMR}$ spectrum of Cd(methHapBsh)$_2$
Figure 3.51: The $^{13}$C-$^1$H NMR spectrum of Ni(methHapBsh)$_2$(H$_2$O)$_2$

Figure 3.52: The $^{13}$C-$^1$H NMR spectrum of [Zn(methHapBsh)]$_2$H$_2$O
UV-visible spectral data:

**Table 3.29:**
Electronic absorption spectra of free ligands and their metal complexes in the UV region:

<table>
<thead>
<tr>
<th>Compound</th>
<th>λ (nm)</th>
<th>M</th>
<th>π → π*</th>
<th>n → π*</th>
<th>LMCT</th>
<th>d-d</th>
</tr>
</thead>
<tbody>
<tr>
<td>methHapBsh</td>
<td>10⁻⁴</td>
<td>205,220,235,245,260,270,280</td>
<td>320</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Cd(methHapBsh)₂</td>
<td>10⁻⁴</td>
<td>205,220,240,255</td>
<td>280,305</td>
<td>330-355</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>[Cu(methHapBsh)]₂</td>
<td>10⁻⁴</td>
<td>230,245,270</td>
<td>290,310,325</td>
<td>335-390</td>
<td>675</td>
<td></td>
</tr>
<tr>
<td>[Ni(methHapBsh)]₂(H₂O)₂</td>
<td>10⁻⁴</td>
<td>240,255</td>
<td>290,305</td>
<td>330,345</td>
<td>670</td>
<td></td>
</tr>
<tr>
<td>[Zn(methHapBsh)]₂H₂O</td>
<td>10⁻⁴</td>
<td>215,230,240,260,275</td>
<td>290,300,320</td>
<td>335,350</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

The electronic absorption data of the ligand (3.5) and its complexes are shown in Table 3.29. It shows a weak band as a shoulder at 320nm assigned to n → π* transition involving molecular orbitals of C=N chromophore and phenyl ring. The band at 205-280 nm range is assigned to π → π* transition of the phenyl ring and azomethine group transition involving molecular orbitals localized on that groups. By comparing of the electronic absorption spectra of the free ligand and its complexes, It is observed that the bands appearing in range 205-280 nm in the ligand shifted to lower energy in all complexes supporting the coordination of the ligand with the metal ion. The spectra of the all complexes of the ligand show low intensity bands at range 330-670 nm due to d-d transition of the metal ion and LMCT (ligand to metal charge transfer bands) transition from the lone pairs of the phenolic oxygen donor to the M(II) ions. Bands in range 280-325 nm are assigned to n → π* transition involving molecular orbitals of the azomethine group chromophore. These bands have lower wavenumbers than the ligand.
as a result to the coordination between the ligand and the metal ion. The Ni(II) and Cd(II) complexes have larger red shifted than and Cu(II) and Zn(II) complexes comparing to the ligand (3.5).

**Thermal analysis:**

The weight loss was measured from 30 °C up to ≈ 900 °C. The weight losses for each chelate were calculated for the corresponding temperature ranges and are shown in table 3.30. The metal percentages calculated from metal oxide residues were compared with those determined by the analytical metal content determination (Macdonald et al., 1969). The Cd(II) complex was stable up to 34.15 °C and its decomposition started at this temperature and was completed at 711.51 °C (Figure 3.53). A mass loss occurred within the temperature range 34.15-167.48 °C corresponding to the loss of hydrated water molecules. The Cd(II) complex decomposed and produced CdO₂ as residue [found(calculated)%: 23.95(20.10)] in three steps in the temperature range 34.15-167.48, 169.01-336.05 and 337.58-711.51°C. In the decomposition process of Cd(II) complex, the mass losses corresponded to 2H₂O, (Ph-SO₂-NH-N)₂CH₃-C-Ph-CH₃ and CH₃-C-Ph-CH₃ respectively.
Figure 3.53: The TGA spectrum of Cd(methHapBsh)$_2$

The Cu(II) complex was stable up to 227.70 °C and its decomposition started at this temperature and was completed at 600.69 °C (Figure 3.54). The Cu(II) complex decomposed and produced Cu$_2$O$_3$ as residue [found(calculated)%: 26.3(26.15)] in two steps in the temperature range 227.70-281.42 °C and 284.49-600.69 °C. In the decomposition process of Cu(II) complex, the mass losses corresponded to (Ph-SO-NH-N)$_2$(CH$_3$-C-Ph)O and CH$_3$-C-Ph-CH$_3$. CH$_3$ respectively.
Figure 3.54: The TGA spectrum of [Cu(methHapBsh)]₂

The Ni(II) complex was stable up to 33.01 °C and its decomposition started at this temperature and was completed at 794.59°C (Figure 3.55). A mass loss occurred within the temperature range 33.01-83.06 °C corresponding to the loss of three hydrated water molecules and at 87.12-141.23 °C corresponding to the loss of two moles of coordinated water molecules. The third step of the composition process occurred within temperature range 142.58-300.85 °C corresponding to the loss of (Ph-SO-NH-N)₂.O.Ph. A mass loss occurred within the temperature range 299.49-375.25 °C corresponding to the loss of CH₃-C-CH₃. The last step of the composition process occurred within temperature range 376.60-794.59 °C corresponding to the loss of CH₃-C-Ph-CH₃. Ni(II) complex decomposed and produced Ni₂O₃ as residue [found(calculated)\%: 26.73(23.00)].
Figure 3.55: The TGA spectrum of [Ni(methHapBsh)]₂(H₂O)₂

Zn (II) complex decomposed and produced ZnO₂ as residue [found (calculated)]%: 16.03 (14.12)% in four steps in the temperature range 45.27-98.50, 98.50-180.63, 182.15-315.98, 315.98-618.64°C (Figure 3.56). A mass loss occurred within the temperature range 45.27-98.50 °C corresponding to the loss of hydrated water molecule and at 98.50-180.63 °C corresponding to the loss of one mole of coordinated water molecule. The third step of the composition process occurred within temperature range 182.15-315.98 °C corresponding to the loss of (Ph-SO₂-NH-N=C-CH₃)₂PhCH₃.CH₃. The last step of the composition process occurred within temperature range 315.98-618.64 °C corresponding to the loss of phenyl ring.
Figure 3.56: The TGA spectrum of \([\text{Zn(methHapBsh)}]_2\text{H}_2\text{O}\)

The Cd(II), Ni(II) and Zn(II) complexes are thermally stable up to around 34-45 °C. The IR spectra of these complexes are characterized by the appearance of a broad band in the region 3400-3448 cm\(^{-1}\), due to the \(\nu\) (-OH) of the water (Sekerci et al., 2000). As it can be seen in Table 3.30, Cu(II) complex is the most stable compound.
Table 3.30:
TGA data of the Cd(methHapBsh)$_2$, [Cu(methHapBsh)]$_2$, [Ni(methHapBsh)]$_2$ and [Zn(methHapBsh)]$_2$H$_2$O:

<table>
<thead>
<tr>
<th>Complex</th>
<th>Step</th>
<th>Temperature (°C)</th>
<th>Weight loss (%)</th>
<th>Assignments</th>
<th>Residue (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Found(Calculated)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cd(II)</td>
<td>1</td>
<td>34.15-167.48</td>
<td>3.78(2.61)</td>
<td>2H$_2$O</td>
<td>CdO$_2$</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>23.95(20.10)</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>169.01-336.05</td>
<td>13.52(13.33)</td>
<td>(Ph-SO$_2$-NH-$N$_2$CH$_3$-C-Ph-CH$_3$)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>337.58-711.51</td>
<td>60.20(60.25)</td>
<td>CH$_3$-C-Ph-CH$_3$</td>
<td></td>
</tr>
<tr>
<td>Cu(II)</td>
<td>1</td>
<td>227.70-281.42</td>
<td>56.25(58.11)</td>
<td>(Ph-SO-\text{-}N$_2$(CH$_3$-C-Ph)O</td>
<td>Cu$_2$O$_3$</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>26.3(26.15)</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>284.49-600.69</td>
<td>17.45(18.00)</td>
<td>CH$_3$-C-Ph-CH$_3$.CH$_3$</td>
<td></td>
</tr>
<tr>
<td>Ni(II)</td>
<td>1</td>
<td>33.01-83.06</td>
<td>7.91(7.46)</td>
<td>3H$_2$O</td>
<td>Ni$_2$O$_3$</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>87.12-141.23</td>
<td>7.66(5.46)</td>
<td>2H$_2$O</td>
<td>26.73(23.00)</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>142.58-300.85</td>
<td>52.49(54.87)</td>
<td>(Ph-SO-\text{-}N$_2$.O.Ph</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>299.49-375.25</td>
<td>6.45(5.80)</td>
<td>CH$_3$-C-CH$_3$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>376.60-794.59</td>
<td>14.33(16.17)</td>
<td>CH$_3$-C-Ph-CH$_3$</td>
<td></td>
</tr>
<tr>
<td>Zn(II)</td>
<td>1</td>
<td>45.27-98.50</td>
<td>1.49(2.61)</td>
<td>H$_2$O</td>
<td>ZnO$_2$</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>98.50-180.63</td>
<td>2.25(2.61)</td>
<td>H$_2$O</td>
<td>16.03(14.12)</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>182.15-315.98</td>
<td>71.49(72.38)</td>
<td>(Ph-SO$_2$-NH-N=C-CH$_3$_2).Ph-CH$_3$.CH$_3$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>315.98-618.64</td>
<td>10.21(10.87)</td>
<td>Ph-</td>
<td></td>
</tr>
</tbody>
</table>
Proposed structures of the (methHapBsh) complexes:

\[
\begin{align*}
M &= \text{Cd(II)} \\
M &= \text{Cu(II)}
\end{align*}
\]
The structures of the metal complexes were proposed as they are in good agreement to elemental analysis, IR, NMR, UV and TGA. According to elemental analysis and TGA measurement, the molecule of Cu(II) and Ni(II) complexes are dimeric via phenolic oxygen bridges. This feature is obtained by (Hapipah et al., 2004).
Chapter 4

Biological Activities
4.1- Acute toxicity studies:

As part of this study, the acute toxicity of benzenesulfanohydrazones and their metal complexes, was investigated in mice. A single administration of the extract by the oral route up to a dose of 5000 mg/kg showed that there are signs of acute toxicity in the treated animals. Most of the treated animals were dead after one day after the experiment. These findings indicate that the acute administration of these compounds (5000 mg/kg) in mice is toxic.

4.2- Anti-ulcerogenic studies:

The administration of ethanol to rats produces gastric mucosal lesions and erosions similar to those occurring in gastric ulcer. These lesions are produced because ethanol can effect the protective defense mechanisms at the mucus (Repetto et al., 2002).

This study describes a model to produce extensive gastric necrosis in rats after induction by an absolute ethanol at animals. Ethanol rapidly penetrate mucosa layer and cause extensive damage once induced to rats (Rajeshkumar et al., 2001). This supported the evidence why only 30 minutes is needed in my study to produce acute gastric ulceration in rats. Administration of absolute ethanol to fasted rats causes severe gastric damage visible from the outside at the stomach as thick reddish-black lines in ulcerated control group as shown in Figure (4.1).

Figure 4.1: view of outside the stomach (a) treated 95-100% inhibition (b) negative control group (tween 20)
The administration of benzenesulfanohydrazones before 30 minutes of administration of absolute ethanol leads to good prevention results in reduce or absence of the lesions. As shown in Figure 4.1 (view of outside the stomach) and Figure 4.2 (opened stomach).

![Image](image-url)

**Figure 4.2:** The open stomach (a) treated 95-100% inhibition (b) negative control group

Histological analysis of ethanol of treated ulcer control rat stomachs revealed the presence of necrotic debrii in lamina propria of the mucosa. The lesions were extending down the mucosa layer involving the surface epithelium (Figure 4.3). The treated groups have less damages along the surface of epithelium. Mucosal blood flow has been attributed to be an important factor in the damage caused by alcohol and is modulated by prostaglandin (*Hollander et al., 1984*). The effectiveness of benzenesulfanohydrazones in prevention against mucosal damage caused by ethanol may indication of its effect on prostaglandin.
The treatment by benzenesulfanohydrazones had reduced the volume of gastric secretion. In cimetidine group the gastric contents of the is around 3.60 g and those of treated groups are in range of (1.01-3.20 g). This characteristic concludes that benzenesulfanohydrazones showed a similar characteristic as histamine H₂ receptor antagonists. This has led to why cimetidine has been used as standard antiulcer drug in present study. Cimetidine has been reported to decrease acid output but did not decrease the ulcer area. This supported the present study which both doses had indicated delivered better cytoprotective effects in reducing ulcer area formation compared with cimetidine with less gastric secretion. Figure 4.4 shows the effect of different compounds on mucus weight.
Figure 4.4: Prevention effect of Benzenesulfanohydrazones (low dose) on mucus weight of rats stomach.

The inhibition of benzenesulfanohydrazones excellent and higher than cimetidine group which has percentage of 88% inhibition. As the dosage was increased further, the ulcer inhibition increased to 100%. The reduced gastric acidity measured after pylorus ligation suggests that the cytoprotective mechanism of action of the extract on gastric mucosa may involve direct inhibition of gastric secretion. The reduction of acidity observed after incubation of gastric juice with the extract suggests that the cytoprotective mechanism
may involve a simple neutralization of the acid secreted in the stomach. Figure 4.5 shows the effect of benzenesulfanohydrazones and its complexes on the acidity of the gastric juice (in range of (PH=3.80-5.84) compared to the cimetidine group (PH=7.00). This agree with different studies done by Murakamu et al., 1990 and Njar et al., 1995.

![Figure 4.5](image)

**Figure 4.5**: Prevention effect of Benzenesulfanohydrazones (low dose) on acidity of the gastric juice of pyloric ligated rats.

In this study benzenesulfanohydrazones and their metal complexes were found to reduce gastric lesions induced by ethanol in vivo-experiment. The results suggested that the anti-ulcer mechanisms of benzenesulfanohydrazones and their metal complexes may be due to the strengthening action on gastric mucosal lining and the suppression of
damaging effects of free radicals. Figure 2.6 shows the inhibition of benzenesulfanohydrazones against the stomach ulcer induced by absolute alcohol and the results are compared to the standard drug, cimetidine.

![Graph showing inhibition percentage of different ligands and metal complexes.](image)

**Figure 4.6**: Prevention effect of Benzenesulfanohydrazone (low dose) against ethanol induced ulcer. Columns represent the inhibition percentage of different ligands and its metal complexes.

Effect of Benzenesulfanohydrazide compounds (low dose 62.5mg/kg, high dose 250mg/kg) on pylorus ligated lesions and gastric secretion in rats are shown in tables 4.1 and 4.2 in pages 98 and 99 respectively.
The main reason for the biological activities of the Schiff bases that they contain nitrogen and other donors (Djebber et al., 1997) and mainly because it contain the azomethine group (Amany et al., 1993). This can be explained as follow:

1- sp² hybridization in both nitrogen and carbon atoms to form C=N:

In azomethine group, both the nitrogen and carbon atoms have sp² hybridization. The three equivalent orbitals are formed by the combination of one 2s and two 2p orbitals of the two atoms. The three sp² hybrid orbitals are directed towards the three corners of a triangle. The remaining one unhybridized p-orbital on each atom, which is perpendicular to the plane of the molecule to form π bond. This bond is weaker and less stable than sigma bond and can easily be polarized. The π electrons are commonly referred to as mobile electrons.

2- Ability to form coordination compounds and chelates:

Also Schiff bases form coordination compounds with the metal atoms. Coordination compound possessing two or more ligands that have donor atoms and whose structure permit the simultaneous attachment of two or more of these sites to the same metal ion, forming one or more rings, are called chelates. Chelates forming five or six-membered rings are more favored owing to the minimal covalent bond angle strain present in them. The precondition for the formation of a chelate by a metal ion is the availability of vacant orbitals on it. Thus the transition elements that have partly filled d or f orbitals, are best suited for complex formation with a variety of ligands, the more interesting among these in the biological systems are the first group transition elements, which are the d-block elements (Talwar et al., 2006).
3- M→L π - or back-bonding:

According to the valence bond theory, large overlap of the orbitals involved in the electron transfer will lead to large interaction energies and therefore to adiabatic reactions. If the ligands have filled or empty π orbitals (p π, d π, or π systems), these orbitals will interact with the d orbitals of the metal ion having t_{2g} symmetry. Ligands having empty π orbitals of higher energy than the metal t_{2g} orbitals may accept electrons from the metal (M→L π - or back-bonding), whereas ligands having filled π orbitals of lower energy than the metal t_{2g} orbitals may donate electrons to the metal (L → M π - bonding). The d orbitals of the central metal having e_{g} symmetry will overlap with ligand orbitals having sigma symmetry. Evidently electron transfer between t_{2g} will be favored by π -bridging orbitals, while electron transfer between e_{g} orbitals by sigma- bridging ligand (Gunther et al., 1973).

4- Can form an Intermolecular and Intramolecular Hydrogen bond:

Hydrogen bond formation is of great importance in biological system. Although the bond energy is low (about 2-5 kcal/mole), the additive effects of several such bonds can stabilize an interaction significantly. Multible hydrogen bond formations are responsible for the ordered structure of nucleic acids and proteins (Talwar et al., 2006).
<table>
<thead>
<tr>
<th>Compound</th>
<th>Mean ulcer area ± S.E.M</th>
<th>Inhibition (%)</th>
<th>Mucus weight (g)</th>
<th>Total gastric contents(ml)</th>
<th>PH of the gastric juice</th>
<th>Gastric acidity (M)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HapBsh</td>
<td>8.00±5.06*</td>
<td>96.20</td>
<td>2.69</td>
<td>6.70</td>
<td>5.84</td>
<td>1.06×10⁻³</td>
</tr>
<tr>
<td>Ni [HapBsh]₂</td>
<td>1.67±1.31*</td>
<td>99.24</td>
<td>1.36</td>
<td>5.20</td>
<td>4.91</td>
<td>2.03×10⁻³</td>
</tr>
<tr>
<td>ClHapBsh</td>
<td>14.00±9.75*</td>
<td>93.34</td>
<td>1.06</td>
<td>6.00</td>
<td>4.25</td>
<td>1.84×10⁻³</td>
</tr>
<tr>
<td>[Cu(ClHapBsh)]₂</td>
<td>6.17±3.15*</td>
<td>97.15</td>
<td>1.54</td>
<td>7.70</td>
<td>4.09</td>
<td>2.62×10⁻³</td>
</tr>
<tr>
<td>[Ni(ClHapBsh)]₂</td>
<td>0.00±0.00*</td>
<td>100.00</td>
<td>1.22</td>
<td>8.50</td>
<td>3.65</td>
<td>2.05×10⁻³</td>
</tr>
<tr>
<td>FHapBsh</td>
<td>7.67±5.31*</td>
<td>96.35</td>
<td>2.00</td>
<td>6.60</td>
<td>4.60</td>
<td>1.63×10⁻³</td>
</tr>
<tr>
<td>Cu[FHapBsh]₂</td>
<td>1.16±1.16*</td>
<td>96.67</td>
<td>3.20</td>
<td>9.20</td>
<td>3.80</td>
<td>4.51×10⁻³</td>
</tr>
<tr>
<td>Zn[FHapBsh]₂</td>
<td>0.00±0.00*</td>
<td>100.00</td>
<td>1.01</td>
<td>11.00</td>
<td>4.66</td>
<td>2.39×10⁻³</td>
</tr>
<tr>
<td>BrHapBsh</td>
<td>2.17±0.95*</td>
<td>98.97</td>
<td>2.23</td>
<td>9.20</td>
<td>5.06</td>
<td>1.16×10⁻³</td>
</tr>
<tr>
<td>[Cu(4BrHapBsh)(DMSO)]₂</td>
<td>12.33±6.82*</td>
<td>94.05</td>
<td>1.50</td>
<td>9.00</td>
<td>5.10</td>
<td>1.20×10⁻³</td>
</tr>
<tr>
<td>methHapBsh</td>
<td>15.00±14.21*</td>
<td>92.87</td>
<td>2.27</td>
<td>8.70</td>
<td>4.19</td>
<td>1.82×10⁻³</td>
</tr>
<tr>
<td>methHapBsh</td>
<td>6.50±6.50*</td>
<td>96.91</td>
<td>1.01</td>
<td>6.20</td>
<td>4.42</td>
<td>2.67×10⁻³</td>
</tr>
</tbody>
</table>

*Statistically significant relative to control group, the mean difference is significant at 0.05 level.
<table>
<thead>
<tr>
<th>Compound</th>
<th>Mean ulcer area ± S.E.M</th>
<th>Inhibition (%)</th>
<th>Mucus weight (g)</th>
<th>Total gastric contents(ml)</th>
<th>PH of the gastric juice</th>
<th>Gastric acidity (M)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HapBsh</td>
<td>2.17±1.38*</td>
<td>98.97</td>
<td>1.53</td>
<td>7.60</td>
<td>4.00</td>
<td>$1.68 \times 10^{-3}$</td>
</tr>
<tr>
<td>Ni [ HapBsh]$_2$</td>
<td>0.00±0.00*</td>
<td>100.00</td>
<td>1.00</td>
<td>11.00</td>
<td>4.25</td>
<td>$5.05 \times 10^{-3}$</td>
</tr>
<tr>
<td>ClHapBsh</td>
<td>0.50±0.50*</td>
<td>99.76</td>
<td>1.01</td>
<td>7.20</td>
<td>3.21</td>
<td>$2.30 \times 10^{-3}$</td>
</tr>
<tr>
<td>[Cu( ClHapBsh )]$_2$</td>
<td>42.33±19.25*</td>
<td>98.00</td>
<td>1.69</td>
<td>5.60</td>
<td>4.64</td>
<td>$2.10 \times 10^{-3}$</td>
</tr>
<tr>
<td>[Ni( ClHapBsh )]$_2$</td>
<td>0.00±0.00*</td>
<td>100.00</td>
<td>1.63</td>
<td>9.60</td>
<td>4.39</td>
<td>$1.85 \times 10^{-3}$</td>
</tr>
<tr>
<td>FHapBsh</td>
<td>6.17±2.47*</td>
<td>97.07</td>
<td>1.05</td>
<td>7.50</td>
<td>3.27</td>
<td>$2.90 \times 10^{-3}$</td>
</tr>
<tr>
<td>Cu[ FHapBsh]$_2$</td>
<td>0.00±0.00*</td>
<td>100.00</td>
<td>3.41</td>
<td>7.00</td>
<td>5.28</td>
<td>$2.81 \times 10^{-3}$</td>
</tr>
<tr>
<td>Zn[ FHapBsh]$_2$</td>
<td>0.50±0.50*</td>
<td>99.76</td>
<td>1.11</td>
<td>11.50</td>
<td>4.90</td>
<td>$2.37 \times 10^{-3}$</td>
</tr>
<tr>
<td>BrHapBsh</td>
<td>6.00±6.00*</td>
<td>99.76</td>
<td>1.43</td>
<td>7.60</td>
<td>3.93</td>
<td>$1.96 \times 10^{-3}$</td>
</tr>
<tr>
<td>[Cu( BrHapBsh )(DMSO)]$_2$</td>
<td>8.67±5.46*</td>
<td>96.40</td>
<td>1.07</td>
<td>10.00</td>
<td>4.86</td>
<td>$1.53 \times 10^{-3}$</td>
</tr>
<tr>
<td>methHapBsh</td>
<td>36.83±14.83*</td>
<td>93.50</td>
<td>1.20</td>
<td>7.20</td>
<td>3.73</td>
<td>$3.62 \times 10^{-3}$</td>
</tr>
<tr>
<td>methHapBsh</td>
<td>0.00±0.00*</td>
<td>100.00</td>
<td>1.26</td>
<td>9.20</td>
<td>3.18</td>
<td>$6.35 \times 10^{-3}$</td>
</tr>
</tbody>
</table>

*Statistically significant relative to control group, the mean difference is significant at 0.05 level.
Chapter 5

Conclusions
5.1- Conclusions:

In the present study, the Schiff bases were formed readily from benzenesulfanohydrazine and substituted 2-hydroxyacetophenone (Cl, F, Br, CH₃). They acted as bidentate ligands to form complex with Cd(II), Cu(II), Ni(II) or Zn(II). These compounds were all characterized with IR, NMR, TGA, UV, elemental analysis and x-ray crystallographic techniques. IR spectra of the ligands show bands around 3400 and 3200 cm⁻¹ assignable to \( \nu (\text{OH}) \) phenolic and \( \nu (\text{N-H}) \) respectively. The decreasing in \( \nu (\text{-OH}) \) wavenumber in the ligand than the free \( \nu (\text{-OH}) \) group (3700-3500 cm⁻¹) is because of participation of (OH) group in intermolecular or intramolecular hydrogen bond as discussed according to the x-ray structure. The ligands then were used to prepare a new family of benzenesulfanohydrazones complexes. In most complexes the ligands were bonded to metal atoms via oxygen and nitrogen donors. This can be investigated by shifting in IR and NMR values or disappearing of the group signals. According to TGA analysis, all the compounds started decomposition and complete at 900 °C. The residue is the metal oxide. benzenesulfanohydrazones are stable in air, melted over 130 °C. They only soluble in solvents such as DMSO, Pyridine or DMF. Vivo studies of anti-ulcerogenic experiment were run for the benzenesulfanohydranones and their metal complexes. The administration of ethanol to rats produces gastric mucosal lesions and erosions similar to those occurring in gastric ulcer. These lesions are produced because ethanol can effect the protective defense mechanisms at the mucus. This study describes a model to produce extensive gastric necrosis in rats after induction by an absolute ethanol at animals. Ethanol rapidly penetrate mucosa layer and cause extensive damage once induced to rats. The data showed that benzenesulfanohydranones were evaluated for their ability to
prevent the gastric mucosa against ulcer induced by absolute ethanol. The possible mechanism was involved in neutralization of the acid secretion in the stomach. The anti-ulcerogenic data were compared to the standard drug, Cimetidine. There was a statistically significant difference in ulcer area of the rats pretreated by benzenesulfanohydrazones compared to Cimetidine. Most of the compounds showed a gastric ulcer inhibition almost 100%, while the Cimetidine drug could prevent ulcer by 88%. However a high dose concentration (5000 mg/kg) of 2-hydroxyacetophenone benzenesulfanohydranones were toxic and killed the rats after one day. So for future studies, are important to lower this toxicity by synthesizing other derivatives of benzenesulfanohydranones. Further studies can also include more specific parameters such as level of gastrin, prostaglandin measurement or vascular permeability. The biological properties of benzenesulfanohydranones can also be tested in vitro (cells) to determine the activity against ulcer causing bacteria, Helicobacter Pylori.
References
References


Repetto and Liesuy (2002). Antioxidant properties of natural compounds used in popular medicine for gastric ulcer. Brazilian Journal of Medical and Biological research 35, 523-534.


List of Published papers and Conferences


Participant for 12th Asian Chemical Congress (12 ACC), Putra World Trade Centre, Kuala Lumpur, 23rd – 25th, August 2007

Poster presented: Schiff Base of Indole Derivatives & Their Complexes; A Biological study on ethanol-induced gastric ulcer. (Ekspo Penyelidikan Rekacipta & Inovasi 2007, University of Malaya).


Participant for Workshop: Improving Research Productivity through Efficient Literature Searching (SCOPUS), University of Malaya.
