

## Short Communication

### Local connectedness in bitopological spaces

H. DASGUPTA

Department of Mathematics, Rishi Bankim Chandra College, Naihati, West Bengal, India.

AND

B. K. LAHRI

Department of Mathematics, Kalyani University, Kalyani 741 235, West Bengal, India.

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#### Abstract

In this paper we introduce the concept of local connectedness in a bitopological space and derive some basic properties of a locally connected bitopological space.

Key words : Bitopological space, component, local connectedness.

#### 1. Introduction

The concept of connectedness in a bitopological space<sup>1</sup> has been introduced by Pervin<sup>2</sup> where he proved some basic theorems on a connected bitopological space. Here we introduce the idea of local connectedness in a bitopological space and obtain some basic properties. We observe with the aid of an example that there are spaces which are locally connected with respect to the two topologies taken separately but the space, considered as a bitopological space, is not locally connected.

#### 2. Known definitions

*Definition-A*<sup>1</sup>. A space  $X$  where two (arbitrary) topologies  $P$  and  $Q$  are defined is called a bitopological space and is denoted by  $(X, P, Q)$ .

*Definition-B*<sup>3</sup>. A bitopological space  $(X, P, Q)$  is called connected iff  $X$  cannot be expressed as the union of two non-empty disjoint sets  $A$  and  $B$  such that

$$[A \cap c_P(B)] \cup [c_Q(A) \cap B] = \phi ;$$

where  $c_P$  and  $c_Q$  denote the closures with respect to  $P$  and  $Q$  topologies respectively. If  $X$  can be so expressed, then  $A$  and  $B$  are said to separate  $X$ . Also in this case  $A$  and  $B$  are called separated sets. A subset  $E$  of  $(X, P, Q)$  is called connected iff the space  $(E, P/E, Q/E)$  is connected.

**Definition-C<sup>3</sup>.** A function  $f$  mapping a bitopological space  $(X, P, Q)$  into a bitopological space  $(X^*, P^*, Q^*)$  is said to be continuous iff the induced mappings  $f_1 : (X, P) \rightarrow (X^*, P^*)$  and  $f_2 : (X, Q) \rightarrow (X^*, Q^*)$  of the topological spaces are continuous.

### 3. New definitions

According to Pervin<sup>3</sup>, components are maximal connected subsets of  $(X, P, Q)$ . If an element  $x$  is a member of some component, then that component will be denoted by  $C(x)$ . We give below a formal definition of  $C(x)$ .

**Definition-1.** Let  $(X, P, Q)$  be a bitopological space and  $x \in X$ . The component  $C(x)$  of  $x$  is the union of all connected subsets of  $X$  containing  $x$ . The sets like  $C(x)$  are called components of  $X$ .

Since it is known<sup>3</sup> that the union of any family of connected sets having a non-empty intersection is a connected set, it follows that  $C(x)$  is connected.

**Definition-2.** A mapping  $f : (X, P, Q) \rightarrow (X^*, P^*, Q^*)$  is said to be open iff the induced mappings  $f_1 : (X, P) \rightarrow (X^*, P^*)$  and  $f_2 : (X, Q) \rightarrow (X^*, Q^*)$  of the topological spaces are open.

**Definition-3.** A bitopological space  $(X, P, Q)$  is called locally connected at a point  $x \in X$  iff for every pair of  $P$ -open set  $U$  and  $Q$ -open set  $V$  each containing  $x$ , there exist connected  $Q$ -open set  $C$  and connected  $P$ -open set  $D$  such that  $x \in C \subset U$  and  $x \in D \subset V$ .  $(X, P, Q)$  is called locally connected iff it is locally connected at every point of  $X$ .

Thus a bitopological space is locally connected iff the family of all connected  $Q$ -open sets is a base for the  $P$ -topology and the family of all connected  $P$ -open sets is a base for the  $Q$ -topology.

**Remark 1:** It follows that if  $(X, P, Q)$  is locally connected, then the family of all connected  $P$ -open sets is a base for the  $P$ -topology and the family of all connected  $Q$ -open sets is a base for the  $Q$ -topology.

**Remark 2:** Local connectedness for a bitopological space is not equivalent to the local connectedness of the two topologies as shown by the following example.

**Example 1:** Let  $(X, P, Q)$  be a bitopological space where  $X = \{a, b, c\}$ ,  $P = \{\phi, X, \{a\}, \{a, b\}, \{a, c\}\}$  and  $Q = \{\phi, X, \{b\}, \{a, b\}, \{b, c\}\}$ . Clearly  $X$  is locally connected with respect to both the topologies  $P$  and  $Q$ , but  $(X, P, Q)$  is not locally connected at  $a$ .



#### 4. Basic properties

The proof of the following theorem is omitted. The property (iii) is obtained from Theorem *F* of Pervin<sup>3</sup>.

**Theorem 1:** In a bitopological space  $(X, P, Q)$ ,

- (i) each component  $C(x)$  is a maximal connected set in  $X$ ,
- (ii) the set of all distinct components of points of  $X$  form a partition of  $X$ ,
- (iii) each  $C(x)$  satisfies the equation

$$C(x) = c_P(C(x)) \cap c_Q(C(x)).$$

**Theorem 2:** A bitopological space  $(X, P, Q)$  is locally connected iff the components of  $P$ -open set are  $Q$ -open sets and the components of  $Q$ -open set are  $P$ -open sets.

*Proof:* Suppose that  $(X, P, Q)$  is locally connected. Let  $G \subset X$  be  $P$ -open,  $C$  be a component of  $G$  and  $\{U\}$  be a basis consisting of connected  $Q$ -open sets. If  $y \in C$ , then because  $y \in G$ , there is a  $U$  with  $y \in U \subset G$ . Since  $C$  is the component of  $y$  and  $U$  is connected, we have that  $y \in U \subset C$ . This shows that  $C$  is  $Q$ -open. Similarly, it follows that the components of  $Q$ -open set are  $P$ -open sets.

For the converse part we see that the family of all connected  $Q$  (resp.  $P$ )-open sets is a base for the  $P$  (resp.  $Q$ )-topology and so  $(X, P, Q)$  is locally connected.

**Theorem 3:** Let  $(X, P, Q)$  and  $(X^*, P^*, Q^*)$  be two bitopological spaces and  $f: (X, P, Q) \rightarrow (X^*, P^*, Q^*)$  be a mapping which is continuous, open and surjective. Then if  $X$  is locally connected,  $X^*$  is also locally connected.

*Proof:* Let  $U$  be any  $P^*$ -open subset of  $X^*$  and  $C$  be any component of  $U$ . As  $f$  is continuous,  $f^{-1}(U)$  is  $P$ -open in  $(X, P)$ . Let  $A$  be any component of  $f^{-1}(U)$ . Since  $X$  is locally connected and since  $f^{-1}(U)$  is  $P$ -open,  $A$  is  $Q$ -open by Theorem 2. Also it is known from Theorem *D* of Pervin<sup>3</sup> that the continuous image of a connected space is connected and so  $f(A)$  is connected and since  $C$  is a component of  $U$ , it therefore follows that either  $f(A) \subset C$  or  $f(A) \cap C = \phi$ . Thus  $f^{-1}(C)$  is the union of collection of components of  $f^{-1}(U)$  and so  $f^{-1}(C)$  is  $Q$ -open. As  $f$  is open and surjective,  $C = f(f^{-1}(C))$  is  $Q^*$ -open. Thus any component of  $P^*$ -open set is a  $Q^*$ -open set.

Similarly we can prove that any component of  $Q^*$ -open set is a  $P^*$ -open set and hence, by Theorem 2,  $X^*$  is locally connected. This proves the theorem.

**Theorem 4:** A bitopological space  $(X, P, Q)$  is locally connected iff, given any point  $x \in X$  and a pair of  $P$ -open set  $U$  and  $Q$ -open set  $V$  each containing  $x$ , there are  $Q$ -open set  $C$  and  $P$ -open set  $D$  each containing  $x$ , and such that  $C$  is contained in a single component of  $U$  and  $D$  is contained in a single component of  $V$ .

*Proof:* Let  $X$  be locally connected,  $x \in X$  and  $U$  be a  $P$ -open set containing  $x$ . Let  $A$  be a component of  $U$  that contains  $x$ . Since  $X$  is locally connected and  $U$  is  $P$ -open, there is a connected  $Q$ -open set  $C$  such that  $x \in C \subset U$ . By Theorem 1,  $A$  is a maximal connected set containing  $x$  and so  $x \in C \subset A \subset U$ . Since components are disjoint sets, it follows that  $C$  is not contained in any other component of  $U$ . Analogous phenomenon will hold if we would start with  $Q$ -open set  $V$  containing  $x$ .

Conversely, we suppose that, given any point  $x \in X$  and any  $P$ -open set  $U$  containing  $x$ , there is a  $Q$ -open set  $C$  containing  $x$  which is contained in a single component  $F$  of  $U$ . Then  $x \in C \subset F \subset U$ . Let  $y \in F$ , then  $y \in U$ . Thus there is a  $Q$ -open set  $O$  such that  $y \in O$  and  $O$  is contained in a single component of  $U$ . As the components are disjoint sets and  $y \in F$ ,  $y \in O \subset F$ . Thus  $F$  is  $Q$ -open.

Thus for every  $x \in X$  and for every  $P$ -open set  $U$  containing  $x$ , there is a connected  $Q$ -open set  $F$  such that  $x \in F \subset U$ .

Similarly, we can prove that for every  $Q$ -open set  $V$  containing  $x$  there is a connected  $P$ -open set  $G$  such that  $x \in G \subset V$ . Thus  $(X, P, Q)$  is locally connected at  $x$ . Since  $x$  is arbitrary,  $(X, P, Q)$  is locally connected. This proves the theorem.

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## Short Communication

### Apparent molar volume of alkali metal formates in formic acid-water mixtures

K. CHOWDOJI RAO AND S. BRAHMAJI RAO

Department of Chemistry, Sri Krishnadevaraya University, Anantapur 515 003, India.

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#### Abstract

The apparent molar volumes of formates of lithium, sodium and potassium in different mixtures of formic acid and water at 30° C have been calculated from the experimentally determined densities. The molar volume increased with concentration in pure water while it decreased with concentration in aqueous formic acid mixtures. At any concentration of the salt the volume varied non-linearly with the composition of the solvent and exhibited a maximum at about 40%, 60% and 80% of formic acid for lithium, sodium and potassium formates respectively.

**Key words:** Apparent molar volume, viscosity, density, alkali metal formates, formic acid.

#### 1. Introduction

Our previous studies on the viscosity<sup>1</sup> and conductance<sup>2</sup> of sodium formate in formic acid-water mixtures indicated points of inflection at about 50% formic acid. In continuation of these studies we have studied the apparent molar volumes of formates of lithium, sodium and potassium in formic acid-water mixtures at 30° C. The results are communicated here.

#### 2. Experimental

Formic acid (Riedel, 98-100%) purified by the standard procedure<sup>3</sup> (density 1.2058 g/ml lit.<sup>4</sup> 1.2073 g/ml; viscosity 1.459 cp lit.<sup>5</sup> 1.465 cp) and conductivity water are used in these studies. Salt solutions and solvent mixtures are prepared by weight. Density measurements are made with a pycnometer as reported<sup>1</sup> earlier.

Table I

Apparent molar volumes ( $\phi_v$ ) of alkali metal formates in formic acid-water mixtures at 30° C

% HCOOH	0.05	0.10	0.20	0.30	0.40	0.50
<b>Lithium formate</b>						
0	24.00	28.30	24.90	25.30	25.60	26.00
20	28.83	28.70	28.54	28.40	28.30	28.20
40	35.23	34.98	34.65	34.43	34.20	34.00
60	33.45	33.55	32.95	32.50	32.15	31.80
80	33.10	32.40	31.40	30.65	30.05	29.50
<b>Sodium formate</b>						
0	23.20	23.70	24.30	24.90	25.30	25.70
20	27.96	27.94	27.86	27.81	27.78	27.74
40	30.80	30.65	30.40	30.20	30.05	29.90
60	32.60	32.30	32.00	31.60	31.40	31.20
80	26.50	26.10	25.60	25.20	24.90	24.60
<b>Potassium formate</b>						
0	31.91	32.06	32.28	32.44	32.56	32.70
20	37.15	36.70	36.10	35.65	35.25	34.90
40	38.80	38.10	37.70	37.40	37.20	36.90
60	38.50	38.40	38.28	38.18	38.11	38.04
80	44.10	42.80	41.00	39.70	38.60	38.40

### 3. Results

Apparent molar volumes ( $\phi_v$ ) are calculated by equation<sup>6</sup> (1) and the data obtained are presented in Table I.

$$\phi_v = \frac{M}{d_0} - \frac{1000 (d - d_0)}{d_0 C} \quad (1)$$

where  $d$  and  $d_0$  are the densities of the solvent and of the solution,  $M$  is the molecular weight of the salt and  $C$  is the concentration.

### 4. Discussion

The apparent molar volume exhibited a linear decrease with salt concentration in aqueous formic acid in contrast to water. At any concentration of the salt the apparent molar



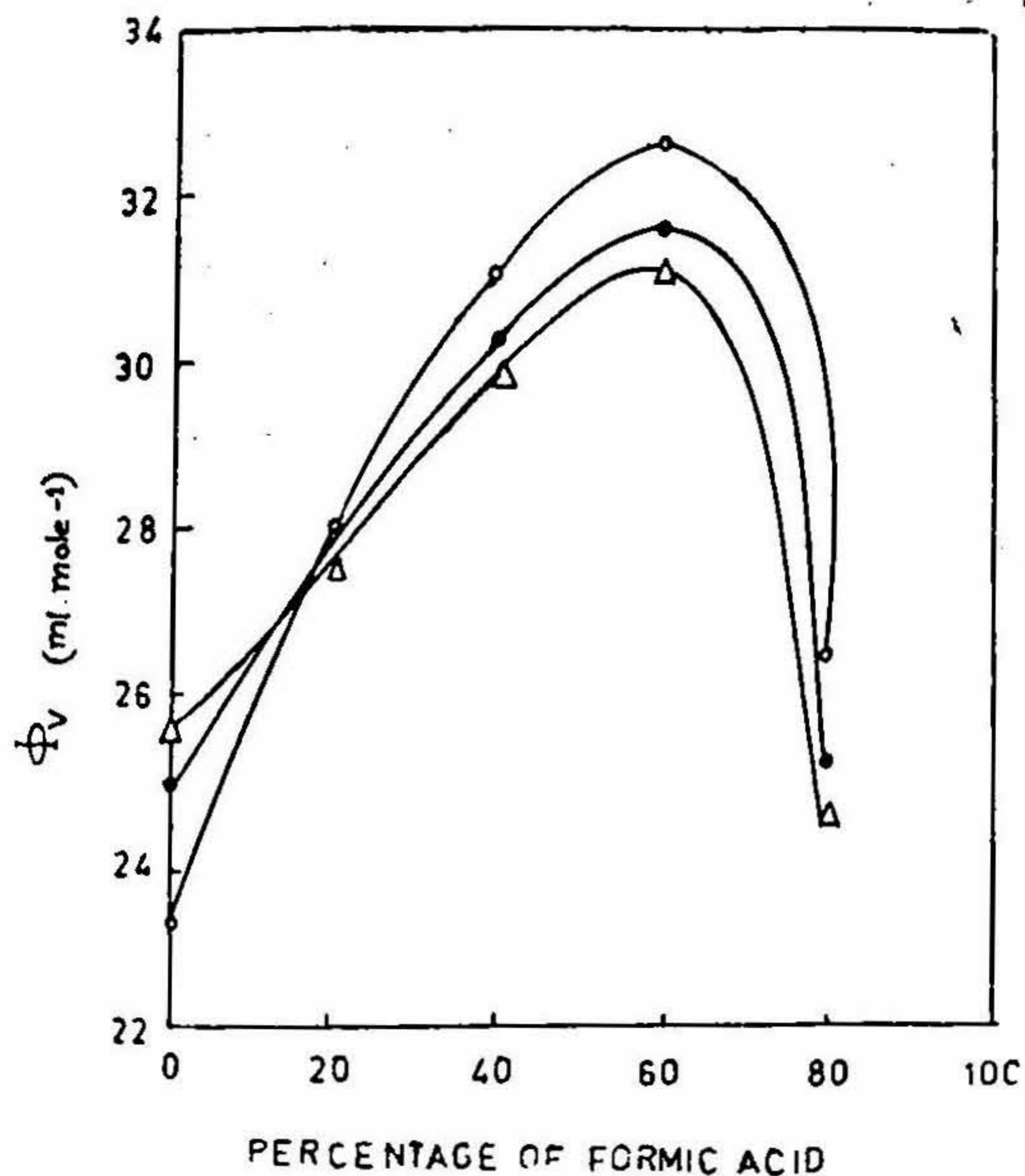


FIG. 1. Plot of  $\phi_V$  vs. percentage of formic acid at 30° C; O, 0.1 molar; ●, 0.3 molar; Δ, 0.5 molar sodium formate solutions.

volume changed with the composition of the solvent in a non-linear fashion exhibiting a maximum (cf. fig. 1). This maximum occurred at 40%, 60% and 80% formic acid for lithium, sodium and potassium formates respectively. The change in viscosity and the packing<sup>7</sup> of the solvent molecules in the ion-solvent complex may be responsible for this maximum. The greater the packing the smaller is the apparent molar volume. It appears that smaller the size of the cation, the minimum solvation (maximum molar volume) occurs at lower percentages of formic acid.

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## Short Communication

### Complexes of Cu (II), Ni (II) and Pd (II) with resacetophenone phenylhydrazone

S. SRIHARI\* AND N. APPALA RAJU

Department of Chemistry, Sri Venkateswara University, Tirupati 517 502, India.

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#### Abstract

The complexes of Cu (II), Ni (II) and Pd (II) with resacetophenone phenylhydrazone have been prepared and characterized by elemental analysis, magnetic measurements, infrared, electronic and ESR spectra, thermogravimetric curves, etc. Based on these data, the complexes are assigned square planar geometry.

Key words: Phenylhydrazone—Cu, Ni, Pd complexes, structural studies.

#### 1. Introduction

Hydrazones, characterized by the presence of triatomic grouping,  $\text{>C=N-N<}$  have been found to be of biological and analytical importance; they act as herbicides, insecticides, plasticizers, antioxidants, etc.<sup>1</sup>. Eight phenylhydrazones of *o*-hydroxyaldehydes and ketones have been synthesized by Raju *et al*<sup>2</sup> and among them resacetophenone phenylhydrazone has been used as gravimetric and amperometric reagent for copper<sup>3,4</sup> and *o*-hydroxyacetophenone phenylhydrazone as a gravimetric reagent for palladium<sup>5</sup>. In the present investigation, the complexes of Cu (II), Ni (II) and Pd (II) with resacetophenone phenylhydrazone (RPPH) have been prepared and characterised on the basis of physico-chemical data.

#### 2. Experimental

RPPH was prepared by the method reported in the literature<sup>6</sup>.

Department of Chemistry, Kakatiya University, Warangal 506 009, India.

The Cu (II) complex was prepared in sodium acetate medium by treating the solution of  $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$  (one mole) in water with RPPH (two moles) in methanol. Similarly, Ni (II) complex was prepared in ammoniacal medium and Pd (II) complex in 0.05 N HCl medium. The precipitate obtained, in each case, was digested on water bath, filtered and washed thoroughly with hot water and then with methanol until the washings were free from the reagent. The complexes were dried in vacuum over fused  $\text{CaCl}_2$ .

The elemental analyses (C, H, N) were obtained from Australian Microanalytical Service, Victoria, Australia. The ultraviolet and visible spectra in DMF were obtained on Toshniwal spectrophotometer (manual). The ESR spectra of the complexes in solid state were recorded at room temperature on Varian E-4 X-band spectrometer available at RSIC, IIT, Madras. The conductance measurements were made in 1,4-dioxan using Toshniwal type CL01/02 A conductivity bridge. The other data were obtained as described previously<sup>7</sup>.

### 3. Results and discussion

The analytical data presented in Table I indicate that the complexes of RPPH can be represented as  $\text{M}(\text{C}_{14}\text{H}_{13}\text{N}_2\text{O}_2)_2 \cdot 2\text{H}_2\text{O}$  where  $\text{M} = \text{Cu}, \text{Ni}$  or  $\text{Pd}$  and are brown yellow and green in colour respectively. The complexes are insoluble in water, dilute mineral acids and common organic solvents such as benzene, chloroform, nitrobenzene, carbontetrachloride, acetonitrile, etc. indicating that they are probably polymeric in nature. The polymeric form may be thought of being due to the formation of intermolecular hydrogen bonds by the free hydroxyl groups present. The complexes are, however, sparingly soluble in DMF and 1,4-dioxan. Because of their insolubility, their molecular weights could not be determined.

Table I

Elemental analysis of metal complexes of RPPH

Complex	Metal %	Carbon %	Hydrogen %	Nitrogen %
Cu $(\text{C}_{14}\text{H}_{13}\text{N}_2\text{O}_2)_2 \cdot 2\text{H}_2\text{O}$	11.37 (10.91)	57.86 (57.77)	4.87 (5.21)	9.71 (9.63)
Ni $(\text{C}_{14}\text{H}_{13}\text{N}_2\text{O}_2)_2 \cdot 2\text{H}_2\text{O}$	10.93 (10.17)	57.43 (58.25)	4.68 (5.25)	9.62 (9.71)
Pd $(\text{C}_{14}\text{H}_{13}\text{N}_2\text{O}_2)_2 \cdot 2\text{H}_2\text{O}$	17.96 (17.02)	54.12 (53.80)	4.50 (4.85)	9.10 (8.97)

Values in parentheses are the calculated ones,



Cu(II) complex is paramagnetic with an effective magnetic moment of 1.75 B.M. This is very close to the spin-only value (1.73 B.M.) with no orbital contribution expected, a case for square planar geometry by virtue of a non-degenerate ground state. The slight excess of magnetic moment over the spin-only value might, however, be due to spin-orbit coupling. Ni(II) and Pd(II) complexes are found to be diamagnetic.

The molar conductance of the complexes in 1,4-dioxan at the concentration  $10^{-3}$  M is too small to measure. The complexes are hence non-electrolytes in this solvent.

The thermograms of Cu(II), Ni(II) and Pd(II) complexes show weight loss in the temperature ranges 100–120° C, 60–120° C and 80–120° C respectively which, in each case, corresponds to the loss of two water molecules. The expulsion of water in the above ranges of temperature indicates that they are present outside the coordination sphere. The sharp decomposition associated with the loss of ligand starts at 192° C, 260° C and 280° C in the case of Cu(II), Ni(II) Pd(II), complexes respectively. The final products of decomposition of the complexes above 550° C correspond, in each case, to metallic oxide.

Some important infrared absorption frequencies are given in Table II.

The absorption peak at  $3310\text{ cm}^{-1}$  in RPPH is not sharp. Since both  $\nu\text{OH}$  and  $\nu\text{NH}$  absorptions fall almost in the same region<sup>8</sup>, they appear to have been merged. A band observed around  $1490\text{ cm}^{-1}$  in the ligand and the metal complexes has been assigned to  $\nu\text{C-N}$ <sup>9</sup>. The C=N stretching frequency occurring at  $1630\text{ cm}^{-1}$  in the ligand is lowered by  $80\text{--}100\text{ cm}^{-1}$  in the complexes suggesting that the nitrogen of azomethine group is coordinating<sup>10</sup>. A band at  $1235\text{ cm}^{-1}$  in the ligand assignable to phenolic  $\nu\text{C-O}$  undergoes a positive shift in the metal complexes. This may be ascribed to the drift of electron density from the oxygen atom to the metal ion resulting in greater ionic character of the C-O bond and a consequent increase in the C-O vibration frequency<sup>11</sup>. It would have been appropriate if the  $\nu\text{C-O}$  in the complexes were compared with  $\nu\text{C-O}$  in the potassium salt of the ligand. This, however, was not possible since the appropriate potassium salt could not be isolated. That the nitrogen of azomethine group and oxygen of *o*-hydroxy group are coordinating, is further evidenced by M-N and M-O bond frequencies (Table II).

The electronic spectrum of Cu(II) complex shows two peaks at  $16660\text{ cm}^{-1}$  and  $22725\text{ cm}^{-1}$  assignable to  ${}^2\text{B}_{1g} \rightarrow {}^2\text{B}_{2g}$  and  ${}^2\text{B}_{1g} \rightarrow {}^2\text{E}_g$  transitions respectively. The former transition is characteristic of square planar geometry<sup>12</sup>. Ni(II) complex gives a peak at  $21050\text{ cm}^{-1}$  and Pd(II) complex at  $14295\text{ cm}^{-1}$  both of which may be assigned to  ${}^1\text{A}_{1g} \rightarrow {}^1\text{A}_{2g}$  transition<sup>13-15</sup>. Two peaks observed at  $33330\text{ cm}^{-1}$  and  $29410\text{ cm}^{-1}$  in the ligand as well as in complexes have been assumed to be due to intra-ligand transitions involving electron transfer.

The ESR spectrum of Cu(II) complex shows two somewhat broad peaks from which  $g_{\parallel}$  and  $g_{\perp}$  have been calculated to be 2.148 and 2.046 respectively. Orbital reduction parameters,  $K_{\parallel}^2$  and  $K_{\perp}^2$  have also been computed and found to be



Table II

IR absorption data (cm<sup>-1</sup>)

RPPH	Cu-complex	Ni-complex	Pd-complex	Assignment
3310	—	—	—	$\nu\text{N-H} + \nu\text{O-H}$
—	3410	3220	3386	$\nu\text{N-H}$
—	3300	3170	3270	Intermolecularly hydrogen bonded O-H
1490	1490	1490	1490	$\nu\text{C-N}$
1630	1550	1530	1530	$\nu\text{C=N}$
1235	1260	1250	1245	$\nu\text{C-O}$
—	485	490	480	$\nu\text{M-N}$
—	370	395	380	$\nu\text{M-O}$

0.3722 and 0.6314 respectively. Kivelson and Neiman<sup>16</sup> have shown that  $g_{\parallel}$  is the most sensitive function for indicating covalency. Normally  $g_{\parallel}$  is 2.3 or more for ionic environments and it is less than 2.3 for covalent environments. The value of  $g_{\parallel}$  obtained for Cu(II) complex is less than 2.3 indicating covalent character of metal-ligand bond in the complex. The observation that  $K_{\parallel}^2$  is less than  $K_{\perp}^1$  further indicates, as pointed out by Hathaway<sup>17</sup>, that the complex is in-plane  $\pi$ -bonded. The spectra of Ni (II) and Pd (II) complexes show no peak and hence they are confirmed to be diamagnetic in nature.

Based on the foregoing data, the complexes are assigned square planar geometry.

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