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Copper(II) Complexes of Schiff Bases Derived from Histamine or 2-(2-Aminoethyl)pyridine and 2,3-Butanedione or 4-Hydroxy-4-methyl-2-pentanone

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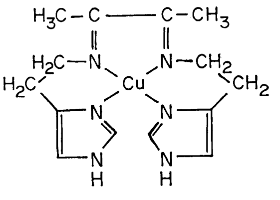
Synopsis. Copper(II) complexes of Schiff bases derived from histamine or 2-(2-aminoethyl)pyridine and 2,3-butanedione or 4-hydroxy-4-methyl-2-pentanone were prepared and characterized by elemental analyses, electronic and ESR spectra, and polarographic half-wave potentials. The relationship between structure of the chelates and the reduction potentials of copper(II) in these complexes was discussed in some detail.

A number of investigations have been carried out for the metal complexes with histidine, histamine, and their related ligands, since the histidine imidazole in metal-containing protein is one of the most important binding sites for metal ions in biological systems.[1)] In connection with hemocyanin models, Simmons *et al.*[2)] have synthesized copper(I) and copper(II) complexes of Schiff bases derived from 2,6-diacetylpyridine and histamine or 2-(2-aminoethyl)pyridine. We have also prepared four copper(II) complexes (**1**—**4**) of Schiff bases produced from histamine or 2-(2-aminoethyl)-pyridine and 2,3-butanedione or 4-hydroxy-4-methyl-2-pentanone, and studied electronic, ESR and electrochemical properties of these complexes for the purpose of elucidating the relationship between the structure of the chelates and the trends toward the formation of copper(I) species from the parent copper(II) complexes, **1**—**4**.



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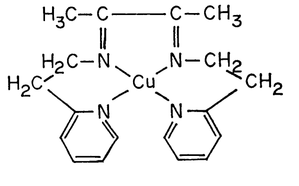

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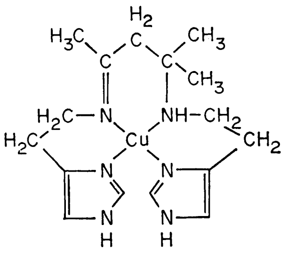

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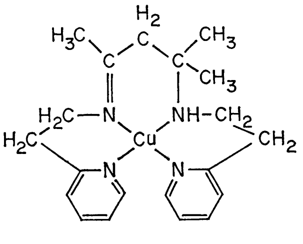

4

Experimental

Preparation of the Complexes. *[Cu(Hist=dia=Hist)]-(ClO$_4$)$_2$*,** ***1***: A mixture of 0.22 g (2.5 mmol) of 2,3-butanedione and 0.56 g (5.0 mmol) of histamine was dissolved in 40 cm^3 of methanol. The mixture was heated under reflux for 2 h. To this was added 0.96 g (2.5 mmol) of copper(II) perchlorate hexahydrate, and the resulting solution was refluxed again for 1 h. After it had been filtered, the filtrate was cooled to give dark violet crystals. Found: C, 30.29; H, 3.98; N, 14.47%. Calcd for $[Cu(C_{14}H_{20}N_6)](ClO_4)_2 \cdot 1.5H_2O$: C, 29.93; H, 4.13; N, 14.96%.

[Cu(2-Aep=dia=2-Aep)](ClO$_4$)$_2$,** ***2***: This complex was prepared by the same method as described for **1** using 2-(2-aminoethyl)pyridine instead of histamine. Found: C, 38.78; H, 3.91; N, 10.63%. Calcd for $[Cu(C_{18}H_{22}N_4)](ClO_4)_2$: C, 38.82; H, 3.99; N, 10.06%.

[Cu(Hist=daa-Hist)](ClO$_4$)$_2$,*** ***3***: A mixture of 0.56 g (5.0 mmol) of histamine and 0.14 g (2.5 mmol) of sodium methoxide was dissolved in 50 cm^3 of acetone, being refluxed for 2 h. To this was added 0.96 g (2.5 mmol) of copper(II) perchlorate hexahydrate, and the resulting solution was heated again under reflux for 2 h. After it had been filtered, the filtrate was allowed to evaporate slowly. Dark blue crystalline products were deposited, being washed with acetone. Found: C, 32.19; H, 4.41; N, 14.13%. Calcd for $[Cu(C_{16}H_{26}N_6)](ClO_4)_2 \cdot 1.5H_2O$: C, 32.46; H, 4.95; N, 14.20%.

[Cu(2-Aep=daa-2-Aep)](ClO$_4$)$_2$,*** ***4***: This complex was prepared by the similar method as described for **3**. Found: C, 40.50; H, 4.74; N, 9.57%. Calcd for $[Cu(C_{20}H_{28}N_4)](ClO_4)_2 \cdot 0.5H_2O$: C, 40.30; H, 4.91; N, 9.40%.

[Ni(Hist=dia=Hist)](ClO$_4$)$_2$. This was prepared by the same way as described for the corresponding copper(II) complex, **1**. Found: C, 31.08; H, 4.11; N, 15.56%. Calcd for $[Ni(C_{14}H_{20}N_6)](ClO_4)_2 \cdot 0.5H_2O$: C, 31.19; H, 3.93; N, 15.59%.

Measurements. IR spectra were recorded with a Hitachi EPI-2 Infrared spectrophotometer by employing the KBr-disk method, visible absorption spectra with a Hitachi 200—10 double beam spectrophotometer. Polarographic measurements were made with a Yanagimoto Polarograph P 8. Water was used as a solvent. Concentration of the copper(II) complexes used was 10^{-3} mol dm^{-3} and the supporting electrolyte used was 0.1 mol dm^{-3} KNO_3. Triton X-100 (0.002%) was employed as a maximum suppressor. The ESR spectra were measured at 77 K on a JEOL-FX-1 X-band ESR spectrometer modulated at 100 kHz. Water containing a small quantity of ethylene glycol was used as a solvent.

** Ligands, Hist=dia=Hist and 2-Aep=dia=2-Aep, represent Schiff bases derived from histamine and 2,3-butanedione, and 2-(2-aminoethyl)pyridine and 2,3-butanedione, respectively.

*** Ligands, Hist=daa-Hist and 2-Aep=daa-2-Aep, represent Schiff bases derived from histamine and 4-hydroxy-4-methyl-2-pentanone, and 2-(2-aminoethyl)pyridine and 4-hydroxy-4-methyl-2-pentanone, respectively.

Table 1. Physical properties of metal complexes

Complex No.	VIS[a)]		$(E_{1/2})_1$ vs. SCE	$(E_{1/2})_2$ vs. SCE	ESR parameters	
	λ_{max}/nm	log ε	V	V	$g_{//}$	$A_{//}$/mT
1	612	2.11	−0.49	−0.83	2.22	19.3
2	613	2.13	−0.48	−0.70	2.22	19.6
3	626	2.14	−0.44	−0.78	2.27	18.6
4	641	2.19	−0.34	−0.68	2.28	16.6

a) Solvent: H_2O-DMSO (1:1).

Results and Discussion

Copper(II) complex **1** of the Schiff base derived from histamine and 2,3-butanedione had been obtained as greenish oily product by Kovacs and Shepherd.[3)] In this work, we isolated the same complex as a dark violet crystal, to which the structural formula **1** was assigned on the basis of elemental analysis and IR spectral data (1620 cm^{-1} (C=N), ≈1100 cm^{-1} (ClO_4)). The corresponding complex **2** of the Schiff base containing 2-(2-aminoethyl)pyridine as amino compound and the complexes, **3** and **4** of Schiff bases derived from histamine or 2-(2-aminoethyl)pyridine and 4-hydroxy-4-methyl-2-pentanone were also isolated as blue-violet crystals. The absorption maxima for the d-d transition band, the half-wave potentials for the reduction of copper(II) at the dropping mercury electrode, and ESR parameters of these complexes are listed in Table 1. The ESR data clearly show that the $A_{//}$ values of complexes **1** and **2** are greater than those of complexes **3** and **4**, respectively, and that the $g_{//}$ values for these complexes decrease in the orders 3>1 and 4>2. The $A_{//}$ values for **1** and **2** with 6—5—6 fused ring structure are remarkably large, indicating that the coordination geometry around copper(II) ion is square-planar. On the other hand, complexes **3** and **4** with 6—6—6 fused-chelate-ring display the increasing trend towards the tetrahedral distortion.[4—6)] The above conclusion is also supported by some other facts. The nickel(II) complex produced from histamine and 2,3-butanedione was isolated as yellowish brown crystals, whereas the attempts to obtain the nickel(II) complex of the Schiff base from histamine and 4-hydroxy-4-methyl-2-pentanone were unsuccessful. In the latter case the color of the reaction mixture did not even change from light green to yellowish brown which is characteristic of square-planar nickel(II) complexes. As shown in Table 1, the half-wave potential for the reduction of Cu(II) to Cu(I) is more negative in **1** than in **3**. In addition, the d-d absorption band of these complexes was observed at a shorter wavelength in **1** than in **3**. The geometrical difference between complexes **1** and **3** may be reflected by the differences observed in their λ_{max} and $(E_{1/2})_1$ values. The same trend is also observed in the comparison of **2** and **4**. It can be considered that the distortion towards a tetrahedral geometry is necessary for stabilizing the copper(I) state. Further the numerical data in Table 1 indicate that if the carbonyl moiety of the Schiff base is same, the half-wave potentials of the copper(II) complexes are more positive with 2-(2-aminoethyl)pyridine than with histamine. This is consistent with the result obtained through a comparison of $[Cu(pyep)]^{2+}$ and $[Cu(imep)]^{2+}$ as reported by Simmons *et al.*[2,7)]

All attempts for preparing the copper(II) complexes of Schiff bases obtained from histamine or 2-(2-aminoethyl)pyridine with 2,5-hexanedione resulted in failure, producing only red-brown powder which could not be characterized as simple compound of definite composition. Further studies of these complexes are now under way.

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7) The following abbreviations are used: imep=2,6-bis-[1-[2-(4-imidazolyl)ethylimino]ethyl]pyridine, pyep=2,6-bis-[1-[2-(2-pyridyl)ethylimino]ethyl]pyridine.