

625. *Reactions of Co-ordinated Ligands. Part I. Hydrolysis and Ester-exchange Reactions of Carboxylic Esters.*

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The chelates (I; R = Et, $n = 2$ and 3) undergo the ester-exchange reactions in neutral solution previously reported for the lower homologue (I; R = Et, $n = 1$). The last chelate reacts slowly with water to give the salt (X; R = R' = H) and the phenol (IV; R = Et, $n = 1$). This reaction is accelerated to a remarkable extent by substituents on the carbon atoms adjacent to the ester groups. A mechanism in which an ester group is activated by co-ordination with a copper ion is suggested for both the hydrolyses and the ester-exchange reactions.

PFEIFFER, OFFERMAN, AND WERNER¹ observed that the chelates (I; $n = 1$) readily underwent ester-exchange reactions under neutral conditions. Martell and Calvin,² who erroneously reported that the ester exchanges were carried out on the chelates (II; $n = 3$ and 4), have explained the rapidity of these reactions by assuming that the nucleophilic character of the acyl carbon atoms is increased by an inductive effect which arises from the co-ordination of the adjacent nitrogen atoms to the metal atom. Frost and Verter,³ however, have pointed out that this effect would also be present in chelates of type (II), which do not readily undergo ester-exchange reactions, and these authors have suggested a mechanism which involves the intermediate (III). In this Paper we report ester-exchange reactions on the chelates (I; R = Et, $n = 2$ and 3) and (IX; a, b, and c), and hydrolysis of the chelates (I; R = Et, $n = 1$) and (IX; a—d). An alternative mechanism which is suggested for the ester-exchange reactions also accounts for the products obtained from the hydrolyses.

The copper chelates of Schiff bases derived from salicylaldehyde and amino-esters were prepared by Pfeiffer, Offerman, and Werner in unstated yields by heating a mixture of bis(salicylaldehydato)copper(II), sodium acetate, and the amino-ester hydrochloride. We have found that the chelates are more conveniently prepared by direct condensation of bis(salicylaldehydato)copper(II) with free amino-esters, which may easily be obtained from their hydrochlorides by the action of ammonia in chloroform.⁴ Thus, condensation of glycine ethyl ester with bis(salicylaldehydato)copper(II) in benzene gave an 87% yield of the chelate (I; R = Et, $n = 1$), which in agreement with Pfeiffer *et al.* gave the corresponding dimethyl ester when refluxed with methanol for 10 minutes. The chelates (I;

¹ Pfeiffer, Offerman, and Werner, *J. prakt. Chem.*, 1941, **159**, 313.

² Martell and Calvin, "Chemistry of the Metal Chelate Compounds," Prentice-Hall, Inc., New York, 1952, p. 399.

³ Frost and Verter, *J. Amer. Chem. Soc.*, 1960, **82**, 85.

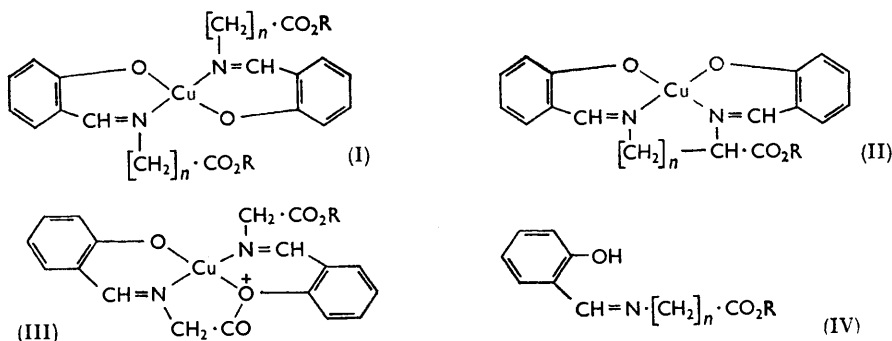
⁴ Hillman, *Z. Naturforsch.*, 1946, **1**, 682.

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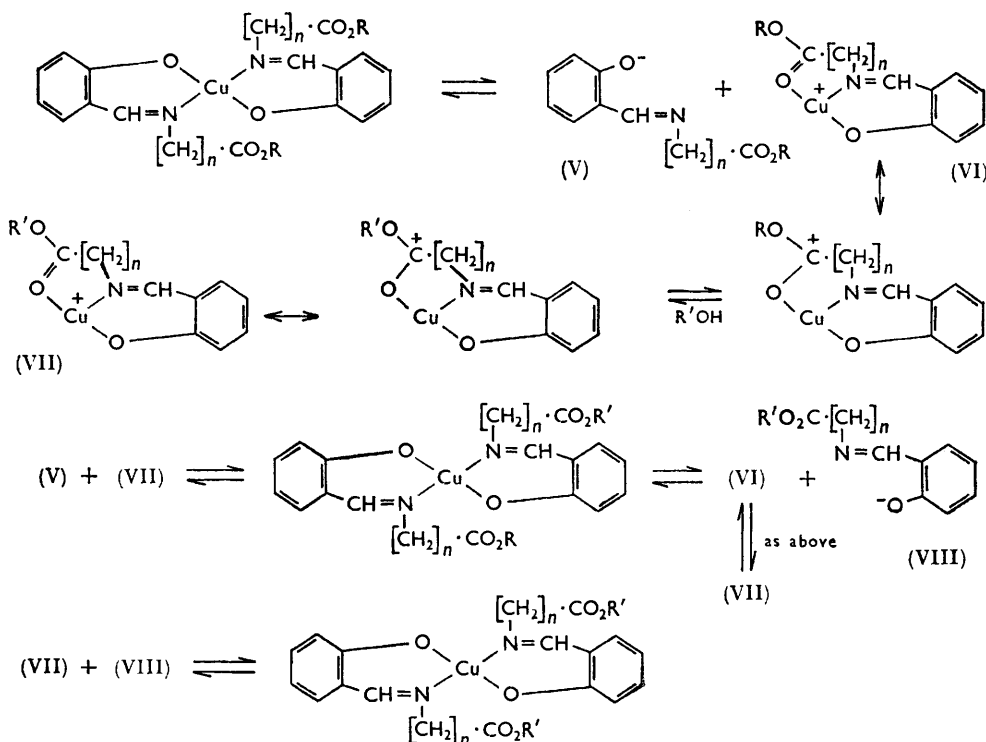
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R = Et, $n = 2$ and 3) were also converted into the corresponding dimethyl esters when refluxed in methanol, but in these cases the periods of refluxing required were about 2 and 18 hours, respectively. The higher homologue (I; R = Et, $n = 5$) was recovered unchanged after 24 hours in refluxing methanol.



When the chelates (I; R = Et, $n = 1, 2, 3,$ and 5) were treated with ethylenediamine-tetra-acetic acid, the parent ligands (IV; R = Et, $n = 1, 2, 3,$ and 5 , respectively) were obtained as viscous yellow liquids. The ligand (IV; R = Et, $n = 1$) showed infrared absorption bands due to the ester groups at 1746, 1195, and 1030 cm^{-1} and the same bands occurred at almost identical frequencies in the spectrum of its copper chelate. This



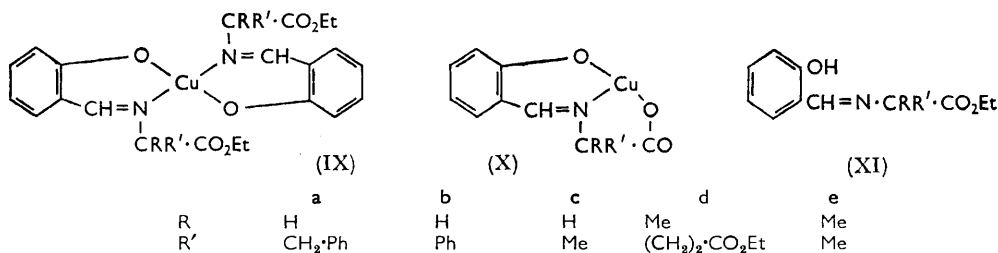
Scheme (a).

indicates that in the solid state the ester groups of the chelate are neither subjected to electron withdrawal nor involved in complex formation, for both these effects would alter

their vibrational frequencies.^{5,6} However, the metal atom is definitely required for the rapid ester-exchange reactions to occur, since the ester (IV; R = Et, $n = 1$) was recovered unchanged from refluxing methanol. An alternative mechanism to that suggested by Frost and Verter is outlined in Scheme (a). The ionisation steps which are postulated are similar to those which occur in a variety of inorganic reactions.⁷ In the cation (VI), co-ordination of the ester group with the copper ion considerably enhances the nucleophilic character of the acyl carbon atom, and consequently the ester group may readily exchange its alkoxy group for that of the solvent alcohol by a mechanism analogous to that which normally operates during acid-catalysed ester-exchange reactions. The interaction between the copper ion and the ester group probably involves the acyl oxygen atom as shown, rather than the alkoxy-one, for it is usually the former that is involved in the formation of complexes with esters.⁶

The substituted chelates (IX; a, b, and c) are markedly less stable than those of type (I) and partly decompose when recrystallised from hot solvents. Their instability probably arises from steric hindrance, for molecular models indicate that these compounds are unable to assume the usual square planar configuration owing to considerable overlap of the phenolic oxygen atoms and the $-\text{CHR}'\text{-CO}_2\text{Et}$ groups. In this connection it is interesting that Sacconi and Ciampolini⁸ have recently reported that the copper chelates of *N*-isopropyl- and *N*-*s*-butyl-salicylideneamines have a pseudo-tetrahedral structure rather than a square planar one.

Condensation of phenylalanine ethyl ester with bis(salicylaldehydato)copper(II) in ethanol afforded the expected chelate (IXa) and a 20% yield of the salt (Xa).^{*} The structure of the salt was indicated by a strong infrared (i.r.) band at 1600 cm^{-1} due to the



carboxylate group⁹ and the formation of salicylaldehyde and phenylalanine hydrochloride when the compound was decomposed with hydrochloric acid. The salt evidently arose from hydrolysis of the diethyl ester (IXa) by water, present in the ethanol as an impurity and also as a byproduct of the initial condensation; for the salt was also formed, together with the expected dimethyl ester, when the diethyl ester was refluxed in technical methanol but not when this solvent was replaced by anhydrous methanol. When the diethyl ester (IXa) was refluxed in 95% aqueous ethanol (v/v) for $1\frac{1}{2}$ hr. the salt was isolated in 80% yield together with the phenol (XIa). Similarly the preparation of the chelate (IXb) and an ester-exchange reaction in technical methanol were both accompanied by formation of the salt (Xb), but this salt was not detected when the exchange reaction was carried out

^{*} The salts (X) are formulated as shown for convenience. The fourth co-ordination position of the copper atom is probably filled either by the salt existing as a dimer,¹⁰ or by the metal atom being co-ordinated to a solvent molecule.

⁵ Bellamy, "The Infra-red Spectra of Complex Molecules," Methuen & Co. Ltd., London, 1954, p. 156.

⁶ Lappert, *J.*, 1961, 817.

⁷ Basolo and Pearson, "Mechanisms of Inorganic Reactions," John Wiley and Sons, Inc., New York, 1958.

⁸ Sacconi and Ciampolini, *J.*, 1964, 276.

⁹ Nakamoto, Morimoto, and Martell, *J. Amer. Chem. Soc.*, 1961, **83**, 4528.

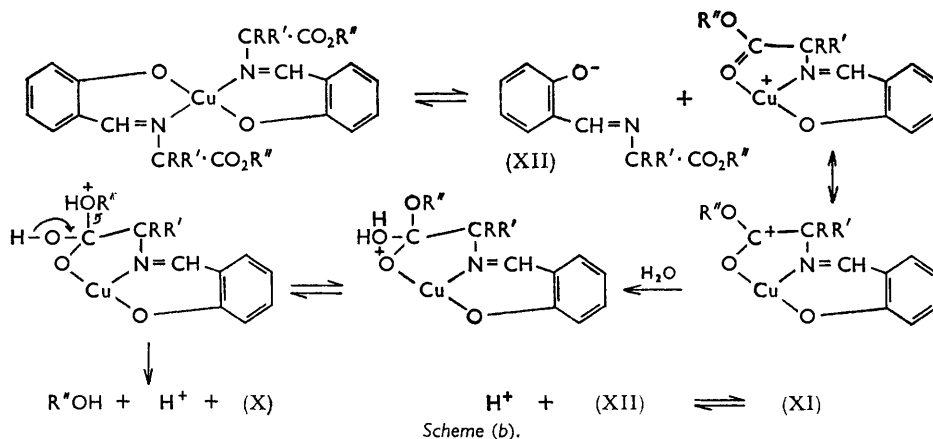
¹⁰ Xubo, Kuroda, Kishita, and Muto, *Austral. J. Chem.*, 1963, **16**, 7.

in anhydrous methanol. From a condensation between alanine ethyl ester and bis(salicylaldehydato)copper(II) only the ester (IXc) was isolated, but with technical methanol this chelate afforded the corresponding dimethyl ester and another chelate which was not obtained pure, but which showed a strong i.r. absorption band due to a carboxylate group.

When the parent chelate (I; R = Et, $n = 1$) was refluxed in 95% aqueous ethanol (v/v) for 8 hr., unchanged starting material (41%) was recovered together with the phenol (IV; R = Et, $n = 1$) and the salt (X; R = R' = H). This salt was not observed during the preparation of the chelate (I; R = Et, $n = 1$), even when the reagents were refluxed in technical ethanol for 1 hr. In contrast the fully substituted chelates (IX; d and e) appear to be so sensitive to water that they cannot be prepared by the usual method, for when bis(salicylaldehydato)copper(II) was shaken with diethyl 2-amino-2-methylglutarate in dry benzene at room temperature only the phenol (XIId) and a salt formulated as (XIId) were obtained. Under the same conditions bis(salicylaldehydato)copper(II) (1 mol.) and ethyl 2-aminoisobutyrate (1 mol.) gave excellent yields of the salt (XIe) and salicylaldehyde. When the ethyl ester in this experiment was replaced by the corresponding *n*-dodecyl ester, *n*-dodecanol was also isolated. In these experiments carefully dried reagents were used, and thus the only water present in the mixtures was that eliminated by condensation of the amines with the bis(salicylaldehydato)copper(II).

The mechanism outlined in Scheme (a) for the ester-exchange reactions may be extended to the hydrolyses, as shown in Scheme (b). The mechanism shown is similar to that suggested by Bender *et al.*¹¹ to account for the catalytic effect of metal ions on the hydrolysis of α -amino-esters in aqueous solution.

It is evident from the hydrolyses that the introduction of substituents on to the carbon atoms adjacent to the ester groups increases the rate of reaction. A similar anomaly was observed when an attempt was made to measure the rates of some of the ester-exchange reactions. With allyl alcohol the diethyl ester (I; R = Et, $n = 1$) afforded the corresponding diallyl ester, which in ethanol was converted back into the diethyl ester. The latter reaction was studied kinetically by using the two absorption bands at 942 and 965 cm^{-1} due to the $-\text{CH}=\text{CH}_2$ groups, and it was found that when a solution (0.005M) of the diallyl ester in 50% ethanol-chloroform was kept at 25°, the intensities of the two absorption bands fell to half their original value after 3–4 hr. Under the same conditions the substituted diallyl ester (IXa; replace Et by $\text{CH}_2\cdot\text{CH}=\text{CH}_2$) appeared to be completely



converted into the corresponding diethyl ester within 1 hr. No starting material was detected after this period, and treatment of the reaction product with ethylenediaminetetraacetic acid gave the phenol (XIa) in 61% yield. (With ethylenediaminetetraacetic acid the pure diethyl ester had given a 76% yield of the phenol).

¹¹ Bender and Turnquest, *J. Amer. Chem. Soc.*, 1957, **79**, 1889.

A possible explanation for these anomalies in terms of the mechanisms outlined above is that in the hydrolyses and ester-exchange reactions the initial step, which involves ionisation of the chelate, is the rate-determining one, and that this proceeds at a faster rate in the reactions with the substituted chelates because of release of the strain caused by the steric hindrance suggested earlier. Alternatively, if the step which involves attack of the activated ester group is the rate-determining one, the effect postulated above must more than compensate for the steric retardation caused by the substituents by greatly increasing the concentration of the ion containing the ester group.

An attempt was made to prepare the chelate (IX; R = H, R' = 2-pyridyl) for it was thought that in the cation of this compound the copper ion would be co-ordinated with the nitrogen atom of the pyridine ring, rather than with the ester group, and that this would prevent the chelate from undergoing the rapid ester-exchange reactions. Condensation of bis(salicylaldehydato)copper(II) with ethyl 2-amino-2'-pyridylacetate¹² gave a deep purple solution from which no solid material was isolated.

Treatment of bis-(3,5-dinitrosalicylaldehydato)copper(II) with glycine ethyl ester gave a good yield of the 3,3',5,5'-tetranitro-derivative of the chelate (I; R = Et, n = 1), but with the ethyl esters of 2-amino-2-phenylacetic acid, phenylalanine, and aspartic acid mixtures were obtained from which no pure compound was isolated.

EXPERIMENTAL

Amino-esters were prepared from optically inactive amino-acids. Infrared spectra of chelates and ligands were measured for Nujol mulls and chloroform solutions respectively. All the chelates described melted with decomposition.

Preparation and Ester-Exchange Reaction of Bis-[N-(ethoxycarbonylmethyl)salicylideneaminato]-copper(II) (I; R = Et, n = 1).—A mixture of bis(salicylaldehydato)copper(II) (16.5 g.), glycine ethyl ester (11.0 g.), and benzene (100 ml.) was warmed (~40°) for 3–4 min., then cooled and filtered to give the chelate (22.0 g., 87%), m. p. 193–199° (lit.,¹ m. p. 200°).

The ester (1.00 g.) was refluxed in allyl alcohol (30 ml.) for 30 min. The solution was cooled and filtered to give bis-[N-(allyloxycarbonylmethyl)salicylideneaminato]copper(II) (870 mg., 83%) as olive-green needles, m. p. 164–165° (Found: C, 57.4; H, 5.0; Cu, 12.7; N, 5.5. C₂₄H₂₄CuN₂O₆ requires C, 57.65; H, 4.8; Cu, 12.7; N, 5.6%).

The *chelates* (I) listed in Table 1 were prepared similarly.

TABLE I.
Chelates (I).

R	n	Yield (%)	M. p.	Found (%)				Formula	Required (%)				
				C	H	Cu	N		C	H	Cu	N	
Me	1	98*	213° †										
Et	2	82 †	109–110	57.1	5.6	12.45	5.4	C ₂₄ H ₂₈ CuN ₂ O ₆	57.2	5.6	12.6	5.6	
Me	2	82*	132–134	55.7	5.1	13.4	6.0	C ₂₂ H ₂₄ CuN ₂ O ₆	55.5	5.1	13.4	5.9	
Et	3	84 †	95–96	59.0	6.1	12.1	5.2	C ₂₆ H ₃₂ CuN ₂ O ₆	58.7	6.1	11.9	5.3	
Me	3	77*	121–122	57.2	5.7	12.3	5.8	C ₂₄ H ₂₈ CuN ₂ O ₆	57.2	5.6	12.6	5.6	
Et	5	83 †	49–50	61.45	6.8	11.0	4.8	C ₃₀ H ₄₀ CuN ₂ O ₆	61.25	6.85	10.8	4.8	

* Prepn. by ester-exchange reaction. † Prepn. by condensation. ‡ Lit.,¹ m. p. 213°.

N-(Ethoxycarbonylmethyl)salicylideneamine (IV; R = Et, n = 1).—The ester (I; R = Et, n = 1) (4.00 g.) in chloroform (50 ml.) was shaken with ethylenediaminetetra-acetic acid (2.5 g.) in water (25 ml.) for 5 min. The chloroform layer was separated, dried (MgSO₄) and evaporated to leave a yellow liquid which solidified on cooling. Recrystallisation from light petroleum (b. p. 40–60°) gave the phenol (2.84 g., 82%) as a yellow solid, m. p. 37–38° (lit.,¹³ m. p. 39°). The product (1.23 g.) obtained when the phenol (1.36 g.) was refluxed in methanol (20 ml.) for 30 min. had m. p. 35–36°, raised to 36–37° on admixture with the starting material.

Table 2 contains the *phenols* (IV) prepared in a similar manner.

¹² Van Zyl, DeVries, Decker, and Niles, *J. Org. Chem.*, 1961, **26**, 3373.

¹³ Gerngross and Izgu, *Comm. Fac. Sci. Univ. Ankara*, 1950, **3**, 149.

TABLE 2.
 Phenols (IV).

R	n	Yield (%)	B. p./mm. or m. p.	n_D	Found (%)			Formula	Required (%)		
					C	H	N		C	H	N
Me	1	68	M. p. 42°		62.4	5.7	7.3	C ₁₀ H ₁₁ NO ₃	62.2	5.7	7.25
Et	2	55	122°/0.5	1.5400 (24°)	65.2	6.75	6.2	C ₁₂ H ₁₅ NO ₃	65.1	6.8	6.3
Et	3	73	131°/0.4	1.5358 (23°)	66.7	7.0	5.7	C ₁₃ H ₁₇ NO ₃	66.4	7.3	5.95
Et	5	86	163°/0.8	1.5285 (20°)	68.6	8.0	5.4	C ₁₅ H ₂₁ NO ₃	68.4	8.0	5.3

N-Acetosalicilylideneaminatocopper(II) (X; R = R' = H).—The diethyl ester (I; R = Et, n = 1) (1.82 g.) was refluxed for 8 hr. in a mixture of dry ethanol (120 ml.) and water (6 ml.). The solvent was removed under reduced pressure and the residue was treated with warm nitromethane (20 ml.) and filtered to give the salt (542 mg., 98% based on recovered starting material) as a pastel-green solid, m. p. 274—275° after crystallisation from dioxan (Found: C, 45.0; H, 2.85; Cu, 25.4; N, 5.8. C₉H₇CuNO₃ requires C, 44.9; H, 2.9; Cu, 26.4; N, 5.8%). The solvent was removed from the filtrate under reduced pressure and the residue was extracted with light petroleum (b. p. 80—100°) to give starting material (749 mg., 41% recovery), m. p. 199°, and the phenol (IV; R = Et, n = 1) (206 mg., 43% based on recovered starting material) both of which were identified by their infrared spectra.

Bis-[N-(1-ethoxycarbonyl-2-phenylethyl)salicilylideneaminato]copper(II) (IXa) and N-2-(3-Phenylpropionato)salicilylideneaminatocopper(II) (Xa).—A mixture of phenylalanine ethyl ester (3.86 g.), bis(salicilylaldehydato)copper(II) (3.06 g.), and ethanol (30 ml.) was warmed (~50°) for 5 min., then cooled and filtered to give the diethyl ester (5.13 g., 78%), m. p. 128—129° raised to 130° by recrystallisation from dry ethanol (Found: C, 65.3; H, 5.5; Cu, 10.3; N, 4.9. Calc. for C₃₆H₃₆CuN₂O₈: C, 65.9; H, 5.5; Cu, 9.7; N, 4.3%). Pfeiffer, Offerman, and Werner¹ obtained a similar analysis but did not report a m. p. The solvent was removed from the filtrate under reduced pressure and the residue was triturated with light petroleum (b. p. 60—80°) to leave the salt (0.71 g., 20%) which crystallised from dioxan as blue-green plates, m. p. 229—230° (Found: C, 55.1; H, 4.6; Cu, 18.5; N, 4.55. C₁₆H₁₃CuNO₃.H₂O requires C, 55.1; H, 4.3; Cu, 18.2; N, 4.0%).

The diethyl ester (1.54 g.) in chloroform (20 ml.) was treated with ethylenediaminetetraacetic acid (0.75 g.) in water (20 ml.) to give N-(1-ethoxycarbonyl-2-phenylethyl)salicilylideneamine (XIa) (1.05 g., 76%) as a viscous yellow liquid, b. p. 156—158°/0.3 mm., n_D^{22} 1.5717, which solidified on prolonged cooling and then had m. p. 33—34° (Found: C, 72.1; H, 6.4; N, 5.0. C₁₈H₁₉NO₃ requires C, 72.7; H, 6.4; N, 4.7%).

Hydrolysis of the Salt (Xa).—The salt (600 mg.) was shaken with 10N-hydrochloric acid (20 ml.) for 5 min. and then water (20 ml.) was added. The mixture was extracted with ether (20 ml.) to remove salicylaldehyde, and treated with hydrogen sulphide. The copper sulphide was filtered off and the filtrate was evaporated under reduced pressure to leave a solid which on trituration with dry ethanol afforded phenylalanine hydrochloride (291 mg., 78%), m. p. and mixed m. p. 235—236°.

Hydrolysis and Ester Exchange Reactions of the Diethyl Ester (IXa).—(a) The ester (1.05 g.) was refluxed in dry methanol (50 ml.) for 1 hr. The mixture was filtered to remove traces of a decomposition product (Cu?) then concentrated under reduced pressure and cooled to give the corresponding dimethyl ester (0.81 g., 80%), m. p. 118—120° (Found: C, 65.2; H, 5.1; Cu, 10.7; N, 4.7. C₃₄H₃₂CuN₂O₆ requires C, 65.0; H, 5.1; Cu, 10.1; N, 4.5%). The material, which was precipitated from the mother-liquors by the addition of light petroleum (b. p. 40—60°), was shown (i.r. spectrum) to be mainly the dimethyl ester and to contain no detectable amount of the salt (Xa).

(b) The ester (530 mg.) was refluxed in technical methanol (100 ml.) for 1 hr., and then the mixture was filtered. The solvent was removed under reduced pressure and the residue was triturated with diethyl ether to leave the salt (Xa) (93 mg., 35%), which was identified by its i.r. spectrum. The ether extract on evaporation gave a green semi-solid (359 mg.) which on recrystallisation from methanol afforded the dimethyl ester (204 mg., 40%), m. p. 118—120°.

(c) A mixture of the ester (1.00 g.), dry ethanol (47.5 ml.), and water (2.5 ml.) was refluxed for 1½ hr. The solution was concentrated under reduced pressure to a volume of about 10 ml., and an equal volume of light petroleum (b. p. 40—60°) was added. The mixture was filtered to

give the salt (Xa) (401 mg., 80%), and the filtrate was fractionated to give the phenol (XIa) (268 mg., 59%), b. p. 165—170°/0.6 mm. The i.r. spectra of both products were identical with those of authentic samples.

Phenylalanine Allyl Ester.—A suspension of phenylalanine (5.00 g.) in dry allyl alcohol (100 ml.) was saturated with hydrogen chloride and the mixture was refluxed for 4 hr. to give the amino-ester hydrochloride (6.72 g., 92%), m. p. 126—127°, which on treatment with ammonia in chloroform gave the free base (4.21 g., 74%), b. p. 121—122°/0.7 mm., n_D^{20} 1.5188; ν_{\max} 1733, 993, and 933 cm^{-1} .

Preparation and Ester-exchange Reaction of Bis-[N-(1-allyloxycarbonyl-2-phenylethyl)salicylideneaminato]copper(II).—A mixture of the preceding amino-ester (2.11 g.), bis(salicylaldehydato)copper(II) (1.56 g.), and benzene (30 ml.) was warmed for several minutes, then concentrated under reduced pressure to about 15 ml., and filtered to give the *diallyl ester* (1.60 g., 46%), m. p. 133—134° raised to 136—137° by crystallisation from benzene—diethyl ether (Found: C, 67.2; H, 5.5; Cu, 9.8; N, 4.5. $\text{C}_{38}\text{H}_{36}\text{CuN}_2\text{O}_6$ requires C, 67.1; H, 5.3; Cu, 9.3; N, 4.1%). The filtrate was diluted with an equal volume of light petroleum (b. p. 80—100°) to give material (576 mg.) which was shown (i.r.) to be mainly the salt (Xa).

A solution of the ester (1.36 g.) in a mixture of dry ethanol (200 ml.) and dry chloroform (200 ml.) was kept for 1 hr. at 25°, then evaporated under reduced pressure at room temperature. The residue in chloroform (20 ml.) was shaken with ethylenediaminetetra-acetic acid (1.17 g.) in water (20 ml.) for 5 min. to give the phenol (XIa) (726 mg., 61%), b. p. 176—178°/0.8 mm., n_D^{20} 1.5678, which had an i.r. absorption spectrum identical with that of an authentic sample.

Bis-[N-(α -ethoxycarbonylbenzyl)salicylideneaminato]copper(II) (IXb) and N-(2-Phenylacetato)salicylideneaminatocopper(II) (Xb).—Bis(salicylaldehydato)copper(II) (13.6 g.) was condensed with ethyl α -amino- α -phenylacetate (11.7 g.) in dry ethanol (100 ml.) in the usual manner. The mixture was filtered to give the *diethyl ester*, m. p. 144—145° after crystallisation from AnalaR benzene (Found: C, 64.6; H, 5.05; Cu, 10.4; N, 4.6. $\text{C}_{34}\text{H}_{32}\text{CuN}_2\text{O}_6$ requires C, 65.0; H, 5.1; Cu, 10.1; N, 4.5%). A second crop (total yield: 22.0 g., 79%) was obtained when the filtrate was concentrated under reduced pressure to a volume of about 20 ml. Gradual addition of diethyl ether to the mother-liquors caused the separation of a mixture of products (980 mg.), followed by the *salt* (810 mg., 6%) as a pale green solid, m. p. 219—221° after crystallisation from dioxan (Found: C, 57.2; H, 3.6; Cu, 20.1; N, 4.6. $\text{C}_{15}\text{H}_{11}\text{CuNO}_3$ requires C, 56.9; H, 3.5; Cu, 20.05; N, 4.4%).

Bis-[N-(α -methoxycarbonylbenzyl)salicylideneaminato]copper(II).—The preceding diethyl ester (1.00 g.) was refluxed in technical methanol (50 ml.) for 1½ hr. and then the solvent was removed under reduced pressure and the residue was dissolved in benzene (5 ml.). Addition of light petroleum (b. p. 40—60°; 10 ml.) caused the separation of the salt (Xb) (363 mg., 65%), which was identified by its i.r. spectrum. Evaporation of the mother-liquors and recrystallisation of the residue from dry methanol gave the *dimethyl ester* (112 mg., 12%), m. p. 155—156° (Found: C, 63.3; H, 4.8; Cu, 11.6; N, 4.5. $\text{C}_{32}\text{H}_{28}\text{CuN}_2\text{O}_6$ requires C, 64.0; H, 4.7; Cu, 10.6; N, 4.7%).

When the diethyl ester (780 mg.) was refluxed in dry methanol (40 ml.) for 30 min. only the dimethyl ester (505 mg., 68%) was obtained.

Preparation and Ester-exchange Reaction of Bis-[N-(1-ethoxycarbonylethyl)salicylideneaminato]copper(II) (IXc).—Alanine ethyl ester (5.38 g.) and bis(salicylaldehydato)copper(II) (7.00 g.) were condensed in ethanol (50 ml.) to give the *chelate* (7.16 g., 62%), m. p. 96—97° (Found: C, 56.6; H, 5.6; Cu, 12.8; N, 5.6. $\text{C}_{24}\text{H}_{28}\text{CuN}_2\text{O}_6$ requires C, 57.2; H, 5.6; Cu, 12.6; N, 5.6%).

A solution of the chelate (275 mg.) in technical methanol (75 ml.) was kept for 1 hr. and then evaporated to dryness under reduced pressure. Addition of light petroleum (b. p. 60—80°; 12 ml.) to a solution of the residue in benzene (8 ml.) caused separation of a pale green solid (20 mg.); ν_{\max} 1625 cm^{-1} . The filtrate was evaporated under reduced pressure to leave *bis*-[N-(1-methoxycarbonylethyl)salicylideneaminato]copper(II) (164 mg., 64%), m. p. 112—113° after crystallisation from dry methanol (Found: C, 55.3; H, 5.3; Cu, 13.5; N, 5.9. $\text{C}_{22}\text{H}_{24}\text{CuN}_2\text{O}_6$ requires C, 55.5; H, 5.1; Cu, 13.4; N, 5.9%).

N-2-(α -Methyl- γ -ethoxycarbonylbutyrate)salicylideneaminatocopper(II) (Xd) and N-2-(2,4-diethoxycarbonylbutyl)salicylideneamine (XId).—A mixture of freshly distilled diethyl 2-amino-2-methylglutarate (1.08 g.), sodium-dried AnalaR benzene (30 ml.), and bis(salicylaldehydato)copper(II) (0.77 g.), which had previously been dried at 100°/0.05 mm. for 24 hr., was shaken for 6 hr. and then concentrated under reduced pressure to a volume of about 10 ml. Addition of

light petroleum (b. p. 40—60°; 40 ml.) gave the *salt* (886 mg., 99%), m. p. 271—272° after crystallisation from dioxan (Found: C, 51.0; H, 5.0; Cu, 17.8; N, 3.7. $C_{15}H_{17}CuNO_5$ requires C, 50.8; H, 4.8; Cu, 17.9; N, 3.95%); ν_{\max} . 1740 and 1600 cm^{-1} . The mother-liquors were filtered through a short column of silica gel and then fractionated to give the *phenol* (517 mg., 64%) as a viscous yellow liquid, b. p. 132—134°/0.4 mm., n_D^{20} 1.5193 (Found: C, 64.5; H, 7.3; N, 3.9. $C_{17}H_{23}NO_5$ requires C, 63.5; H, 7.2; N, 4.4%); ν_{\max} . 1733 and 1742 cm^{-1} .

N-Isobutyrosalicylideneaminatocopper(II) (Xe).—(a) Ethyl α -aminoisobutyrate (2.62 g.), sodium-dried AnalaR benzene (50 ml.), and bis(salicylaldehydato)copper(II) (6.12 g.) were shaken for 3 hr. The mixture was concentrated under reduced pressure to about 10 ml. and filtered to give the *salt* (5.19 g., 98%) as a bluish-green solid, m. p. 251—252° (Found: C, 49.5; H, 4.3; Cu, 23.6; N, 5.5. $C_{11}H_{11}CuNO_3$ requires C, 49.2; H, 4.1; Cu, 23.6; N, 5.2%). Recrystallisation from methanol afforded a *hydrate* which re-formed the anhydrous material at 100°/0.1 mm. (Found: C, 46.5; H, 4.5; Cu, 22.7; N, 5.3. $C_{11}H_{11}CuNO_3 \cdot \frac{1}{2}H_2O$ requires C, 47.5; H, 4.4; Cu, 22.9; N, 5.0%). The filtrate was passed through a short column of silica gel and fractionated to give salicylaldehyde (1.90 g., 78%), b. p. 79—80°/17 mm., identical (i.r. spectrum) with an authentic sample.

(b) *n*-Dodecyl α -aminoisobutyrate¹⁴ (2.72 g.) and bis(salicylaldehydato)copper(II) (3.06 g.) were shaken in sodium-dried benzene (50 ml.) for 6 hr. Isolation of the products as described in the previous experiment afforded the *salt* (2.56 g., 95%), salicylaldehyde (862 mg., 71%), and *n*-dodecanol (1.16 g., 62%), b. p. 140—150°/15 mm., which was identified by its infrared spectrum.

Preparation and Condensation of Bis-(3,5-dinitrosalicylaldehydato)copper(II).—3,5-Dinitrosalicylaldehyde¹⁵ (2.12 g.) in ethanol (10 ml.) was added to copper acetate (1.27 g.) in a mixture of ethanol (5 ml.) and water (10 ml.). The *chelate* (1.74 g., 71%) separated as a pastel-green solid, m. p. 314° (with explosion) after crystallisation from ethanol (Found: C, 36.8; H, 2.2; Cu, 12.85; N, 10.0. $C_{14}H_6CuN_4O_{12} \cdot C_2H_5OH$ requires C, 36.1; H, 2.3; Cu, 11.95; N, 10.5%).

Condensation of the *chelate* (1.22 g.) with glycine ethyl ester (0.52 g.) in ethanol (20 ml.) gave *bis*-[*N*-(ethoxycarbonylmethyl)-3,5-dinitrosalicylideneaminate]copper(II) (1.37 g., 83%) as olive-green plates (from acetone), m. p. 225—226° (Found: C, 40.6; H, 3.4; Cu, 9.8; N, 12.75. $C_{22}H_{20}CuN_6O_{13}$ requires C, 40.3; H, 3.1; Cu, 9.7; N, 12.8%).

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¹⁴ Jacobsen, *J. Amer. Chem. Soc.*, 1946, **68**, 2628.

¹⁵ Hill and Robinson, *J.*, 1933, 486.