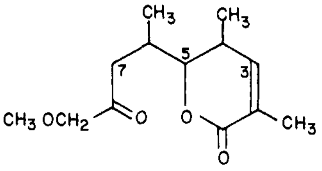
dehyde XIV, formed by vinylogous β-elimination of the C.13 oxygen. XIV was isolated as its dinitrophenylhydrazone, $C_{14}H_{16}N_4O_4$, m.p. 177–178° λ_{max} 265, 301 and 389 mμ.[10] This aldehyde establishes the position of the original ketone at C.9 relative to the lactone hydroxyl at C.13.

The acid, XIII, which does *not* lactonize, loses desosamine (C.5) and water (C.2–C.3) on benzene-hydrochloric acid hydrolysis and now lactonizes to the C.1–C.5 lactone, XV, $C_{13}H_{20}O_4$, dinitrophenylhydrazone m.p. 194–196°. The positions of the C.3 and C.5 hydroxyls relative to the carboxyl and the presence of desosamine at C.5 in XIII, and



XV

hence in oleandomycin are thus established. Oleandrose cannot be linked to desosamine,[2] and must therefore be attached at C.3, the only alternative site.

The structure of oleandomycin therefore is I.

(10) F. Bohlmann, *Ber.*, **84**, 490 (1951), quotes data for analogous compounds.

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RECEIVED MAY 12, 1960

REDUCTION OF POLYPEPTIDE-COBALT(III) COMPLEXES[1]

Sir:

The proposal that electron conduction may be a function of proteins has been an intriguing one.[2] We report here results suggesting the occurrence of some form of electron transfer through peptides during an oxidation-reduction reaction involving polypeptide ligands.

For the reduction of carboxylatopentamminocobaltic ions by chromous ion, Taube has shown that if the carboxylato moiety allows the reductant to donate its electron at a point remote from the cobalt (*e.g.*, some conjugated unsaturated acids), the consequent decrease in repulsion of the two ions at the transition state results in an increase in reaction rate several hundredfold.[3] We have applied this sensitive system to the polypeptide case, where a conduction process would reduce coulombic effects and provide a choice of sites at which an electron might be injected for reduction of a cobalt atom.

Two water-soluble copolymers of DL-alanine and L-glutamic acid, with monomer ratios 5.2 ala/glu and 2.7 ala/glu, were treated with aquopentamminocobaltic perchlorate. Dialysis afforded purified carboxylatopentamminocobaltic complexes, which exhibited absorption maxima identical with those of non-polymeric complexes such as acetatopentamminocobaltic ion (λ_{max} = 503 mμ, ϵ = 71).[4] No cobalt is bound by poly-DL-alanine itself under these conditions. The glutamic acid residues, and thus the cobalt atoms, are approximately randomly distributed, since the carboxyls of the 5.2/1 copolymer titrate in 0.1 *M* potassium chloride as independent groups with *pK* 4.0.

The cobalt-containing products, and their precursors, have a helical α-structure similar to that of poly-DL-alanine.[5,6] Films of these polymers undergo the infrared spectral changes shown by the homopolymer:[5] $\nu_{C=O}$ 1655 cm.$^{-1}$ (α form), converted to 1655, 1625 cm.$^{-1}$ ($\alpha + \beta$) by water at 100°, back to 1655 cm.$^{-1}$ by formic acid. In deuterium oxide the polymers exhibit $\nu_{C=O}$ 1640 cm.$^{-1}$ (α) plus a shoulder at 1660 cm.$^{-1}$ corresponding to a solvated form.[7]

Reduction by chromous ion of these polymeric complexes and of several simpler analogs was followed by disappearance of the 500 mμ absorption. The results are given in Table I.

TABLE I

REDUCTION OF CARBOXYLATOPENTAMMINOCOBALTIC PERCHLORATES BY CHROMOUS ION[a]

$$Cr^{++} + [L\text{-}Co(NH_3)_5]^{++} \xrightarrow{k} [Cr\text{–}L]^{++} + Co^{++} + 5NH_3$$

L	T, °C.	k, M^{-1} sec.$^{-1}$	% of reaction
Acetate	25	0.15[b]	.....
Glycinate	26	.06	.....
Acetylglycinate	26	.30	.....
γ-Acetylaminobutyrate	26	.23	.....
Succinate	25	.19[b]	.....
Copolymer 5.2/1[c]	16.5	>40[e]	44–64[f]
		0.08	20[f]
Copolymer 2.7/1[d]	16.5	>40[e]	50–75[f]
		0.1	50–20[f]

[a] 0.5 *M* $HClO_4$, μ = 1.0, [Co] = 0.002–0.005 *M*, [Cr] = 0.005–0.02 *M*. Complete solution at all times. [b] Ref. 3. [c] Equivalent weight/Co, 560. [d] Equivalent weight/Co, 900. [e] Portion of reaction complete in less than 5 sec. [f] The relative fractions of fast reaction, transition period, and measurable second order rate varied from run to run. The smaller constants correspond to the last portion of reaction.

From the table, it will be seen that the first 50% of the reduction of the polymeric complexes occurs at least two hundred times faster than that of the monomeric complexes. One explanation of this rapid reaction may be that the transition state is stabilized by chelation of chromium. Against this interpretation may be argued the acidity of the medium and the evidence that systems in which chelation is possible, *e.g.*, the acetylglycine and suc-

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(1) Supported by U. S. Public Health Service Grant E-1824 and National Science Foundation Grant 5717.

(2) A recent discussion of the subject appears in *Discussions Faraday Soc.*, **27**, (1959), "Energy Transfer with Special Reference to Biological Systems," Part II, p. 111 ff.

(3) H. Taube, "Mechanisms of Redox Reactions of Simple Chemistry," in "Advances in Inorganic and Radiochemistry," Vol. I, H. J. Emeleus and A. G. Sharpe, editors, Academic Press, Inc., New York, 1959, p. 25; H. Taube, *Can. J. Chem.*, **37**, 129 (1959).

(4) D. K. Sebera, Ph.D. Thesis, University of Chicago, 1959.

(5) A. Elliott, *Nature*, **170**, 1066 (1952).

(6) A. Berger and K. Linderstrøm-Lang, *Arch. Biochem. Biophys.*, **69**, 106 (1957).

(7) E. R. Blout and M. Idelson, THIS JOURNAL, **80**, 4909 (1959).

cinic acid complexes, do not exhibit enhanced reaction rates. An "adsorption" mechanism is ruled out, for the rate of reduction of aquopentamminocobaltic perchlorate is not affected by the mere presence of cobalt-free polymer. We lean to the hypothesis that the rapid reaction corresponds to those cobalt-bearing sidechains of which the carboxyl groups overlap an extended system of hydrogen-bonded amide groups; and that electron transfer from chromium occurs *through* this system.

The products of the reduction of the polymeric complexes have been isolated by dialysis and lyophilization of the reaction mixture They contain chromium equivalent to the initial cobalt, but the sites of this bound chromium are not known. These products are not entirely soluble in water and dissolve sluggishly in formic acid. A film of the polymer has $\nu_{C=O}$ 1650 cm.$^{-1}$, but treatment with water at 100° does not produce any β-form (1625 cm.$^{-1}$). It is conceivable that the rapid reduction process produces a change in the conformation of the polymer which constrains the remainder of reaction to occur by a process involving direct chromium attack at the carboxyl bearing the oxidant.

We are grateful to Professor Henry Taube for his interest in this work.

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RECEIVED APRIL 25, 1960

THE ISOMERIZATION OF TRIALKYLACETIC ACIDS IN SULFURIC ACID[1]

Sir:

Trialkylacetic acids have been found to isomerize in concentrated sulfuric acid under conditions which do not result in significant decarbonylation. The same mixture consisting chiefly of 2,2-dimethylvaleric acid (I)[2] and 2-methyl-2-ethylbutyric acid (II)[2] resulted from the isomerization of either I or II in concentrated sulfuric acid. Solutions of either I or II (0.27 molar) in 94.9% sulfuric acid approached the equilibrium ratio (I/II) of 2.84 with first order kinetics and a half life of 51 minutes at 26.3°. The appearance of a third component 2,2,3-trimethylbutyric acid (III),[3] proceeded much slower. This acid accounted for *ca.* 3% of the mixture after three hours and became about equal to II after 48 hours. The isomerization of III under these conditions slowly yielded I and II in the ratio of 2.84.

Acid II was isomerized in sulfuric acid, the mixture of carboxylic acids separated and converted to the amides. From this mixture the pure amide of I[2] (identified by infrared, m.p. and mixed m.p. 94-95°) was isolated by fractional crystallization. The acid mixtures were analyzed by gas chromatography of the corresponding alcohols (obtained by $LiAlH_4$ reduction) using a 12′ column of Resoflex[4] R-726 on fire brick. Infrared spectrograms of isomerized mixtures were identical with appropriate mixtures of I, II, and III.

The four nine carbon tri-*n*-alkylacetic acids were interconverted rapidly under the same conditions to yield 2,2-dimethylheptanoic acid as the major component. This emphasizes the general nature of this isomerization. The disappearance of 2,2-diethylvaleric acid, which represented *ca.* 1% of the isomerized mixture, proceeded by initially first order kinetics with a half life of less than five minutes. Slower changes occurred to yield products which are presumably analogous to III. The thermodynamically most stable species appear to predominate in isomerized mixtures of both the seven and nine carbon trialkylacetic acids.[5]

That this isomerization occurred at least in part by a decarbonylation-carbonylation process was demonstrated by the exchange of radioactive II (labeled with C^{14} in the carboxyl carbon) in concentrated sulfuric acid with unlabeled carbon monoxide.[6] Also, slow introduction of 2-methyl-2-butene into a sulfuric acid solution of II resulted in the formation of 2,2-dimethylbutyric acid.

The author thanks Messrs. P. L. Gant and R. D. Gallagher for assistance in the tracer experiment and Dr. M. G. Ettlinger for a helpful discussion.

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[1] Presented at the 6th Tetrasectional Meeting of the Oklahoma Sections of the American Chemical Society, March 26, 1960.

[2] Compound I was prepared by oxidation of 2,2-dimethyl-1-pentanol obtained from the Carbide Chemical Corporation, and II was prepared from the Grignard. The melting points of the amides (94-95 and 74-75°) and the physical properties of the acids agree with values previously reported; D. V. N. Hardy, *J. Chem. Soc.*, 464 (1938).

[3] F. C. Whitmore and K. C. Laughlin, THIS JOURNAL, **55**, 3735 (1933).

[4] Cambridge Industries Co., Inc.. Cambridge, Mass.

[5] Similar reactions in which the more stable isomer predominated have been reported by R. E. Pincock, E. Grigat and P. D. Bartlett, THIS JOURNAL, **81**, 6332 (1959); G. Stork and M. Bersohn, *ibid.*, **82**, 1261 (1960).

[6] A carbonylation–decarbonylation mechanism has been demonstrated to occur in the isomerization of cinenic acid to geronic acid by J. Meinwald, H. C. Hwang, D. Christman and A. P. Wolf, *ibid.*, **82**, 483 (1960).

RESEARCH AND DEVELOPMENT DEPARTMENT
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RECEIVED APRIL 16, 1960

THE ISOLATION OF THE ICOSAHEDRAL $B_{12}H_{12}^{-2}$ ION

Sir:

In 1955 Longuet-Higgins and Roberts[1] predicted that the $B_{12}H_{12}$ icosahedron would be stable only as the $B_{12}H_{12}^{-2}$ ion. We now wish to report the isolation of such an ion, in very low yield, from the reaction of 2-iododecaborane with triethylamine.

Sixteen grams of pure 2-iododecaborane and 35 g. of triethylamine were dissolved in 500 ml. of dry benzene and maintained at the reflux temperature for 5 hours. The yellow semi-solid which separated was treated with 150 ml. of acetone, the resulting solid separated by filtration and washed with water to remove the triethylammonium salt[2] of $B_{10}H_{10}^{-2}$ formed as a by-product. The residual solid was recrystallized twice from acetonitrile and ethanol to yield 1.4 g. (3.8%) of the triethylammonium salt of $B_{12}H_{12}^{-2}$ (I). Calcd.: B, 37.54; C, 41.63; H, 12.72; N, 8.09. Found: B, 37.48; C, 40.86; H, 12.97; N, 8.08.

Treatment of I with two equivalents of potassium hydroxide in boiling water displaced triethylamine

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[1] H. C. Longuet-Higgins and M. Roberts, *Proc. Royal Soc. (London)*, **A230**, 110 (1955).

[2] M. F. Hawthorne and A. R. Pitochelli, THIS JOURNAL, **81**, 5519 (1959).