

of patents on such polymerization of olefinic compounds have appeared. In continuing the theoretical studies³ of olefin polymerization in this Laboratory, we have been led to investigate the action of boron trifluoride on alcohols, a type of reaction which has not been reported previously. This is of particular interest since this halide is believed to yield true polymerization products by its action on isobutylene at low temperatures.⁴

We have found that the action of boron trifluoride on isopropyl alcohol proceeds with the formation of polymerized products and from the reaction mixture we have isolated substantial yields of tetrapropylene.

Boron trifluoride (1400 g.) was dissolved in 2 kg. of isopropyl alcohol with external cooling and the resulting solution was heated in a loosely-

(3) Whitmore, *Ind. Eng. Chem.*, **26**, 94 (1934).

(4) I. G. Farbenindustrie, British Patent 401,297.

capped bomb at 100°. The reaction proceeded spontaneously with liberation of much boron trifluoride and other gases (propylene, the dimer, etc.). The contents of the bomb consisted of an upper layer of colorless polymer and a lower aqueous layer. The former was removed, washed free of acid, dried over anhydrous potassium carbonate and fractionated through a 12-plate distilling column of the type used in this Laboratory.⁵ Figure 1 shows the course of the distillation. The tetrapropylene, b. p. 94–105° at 30 mm., n_D^{20} 1.4358–1.4406, is about 20% of the 1200 g. of polymer formed from two kilograms of isopropyl alcohol. Investigation of the products is in progress.

(5) Whitmore and Lux, *THIS JOURNAL*, **54**, 3448 (1932).

SCHOOL OF CHEMISTRY AND PHYSICS
THE PENNSYLVANIA STATE COLLEGE
STATE COLLEGE, PENNSYLVANIA

RECEIVED FEBRUARY 23, 1939

COMMUNICATIONS TO THE EDITOR

THE TOTAL SYNTHESIS OF THE SEX HORMONE EQUILENIN

Sir:

Although certain sex hormones such as estrone have been prepared from other naturally occurring compounds possessing similarities in structure, the total synthesis of none of them has yet been reported. We have now succeeded in accomplishing the total synthesis of the sex hormone equilenin, and in view of Marker's conversion of equilenin to estrone by reduction [*THIS JOURNAL*, **60**, 1897 (1938)] it follows that the total synthesis of both equilenin and estrone has been accomplished.

The reactions which were used are fairly obvious ones and the successful preparation of the hormone depended principally on developing the proper conditions for making the reactions proceed. As a matter of fact, some features of the method had been explored by other investigators without success. The starting point was the known 7-methoxy-1-keto-1,2,3,4-tetrahydrophenanthrene, prepared from 1-naphthylamine-6-sulfonic acid (Cleve's acid).

An eleven-step synthesis converted this compound to equilenin. First of all this ketone was

condensed with methyl oxalate to give a 1-keto-2-glyoxalate derivative which by elimination of carbon monoxide yielded 7-methoxy-1-keto-2-carbomethoxytetrahydrophenanthrene. As early as 1932 Haworth [*J. Chem. Soc.*, 1125 (1932)] prepared the corresponding ethyl glyoxalate from 1-keto-tetrahydrophenanthrene but was unable to eliminate carbon monoxide without decomposing the compound. Under the proper conditions we were able to obtain the 2-carbomethoxy ketone in 89–91% yields. This compound readily was converted to the important intermediate, 7-methoxy-1-keto-2-methyl-2-carbomethoxytetrahydrophenanthrene (m. p. 84.5–86°) in excellent yield. From this point more or less standard procedures were employed to build up the five-membered ring. The Reformatsky reaction followed by dehydration and reduction of the unsaturated acid served to introduce an acetic acid group in the 1-position. As was expected, the product consisted of two racemic mixtures. These readily were separated into the *cis* (m. p. 228–230°) and the *trans* (m. p. 208–210°) 7-methoxy-1-acetic acid-2-methyl-2-carboxytetrahydrophenanthrene. Each of the acids was car-

ried through the remaining steps, which consisted first in lengthening the acetic acid chain to a propionic acid chain through the Arndt-Eistert reaction. The dimethyl ester of the *trans*-7-methoxy-1-propionic acid-2-methyl-2-carboxytetrahydrophenanthrene (m. p. 101–102°) was cyclized by sodium and the product was converted to *d,l*-equilenin by the usual hydrolysis and decarboxylation, including the hydrolysis of the methoxy group. The synthetic equilenin crystallized from benzene in thin colorless plates which melted at 265–267° (natural equilenin, 258°) to a red liquid. The structure of the synthetic equilenin was established definitely by its conversion to 3',3'-dimethyl-7-methoxy-1,2-cyclopenteno-phenanthrene, identical with the compound obtained from natural equilenin by the procedure of Cohen, Cook and Hewett [*J. Chem. Soc.*, 445 (1935)], the method employed by these investigators to establish the structure of equilenin. The synthetic equilenin was resolved by converting it to its *l*-menthoxyacetic ester, from which was isolated the ester which proved to be identical (mixed melting point) with the *l*-menthoxyacetic ester (m. p. 172–174°) of natural equilenin.

DEPARTMENT OF CHEMISTRY
UNIVERSITY OF MICHIGAN
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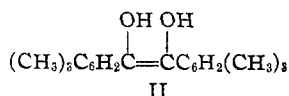
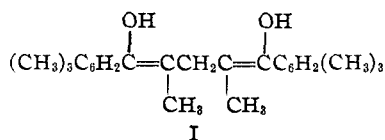
W. E. BACHMANN
WAYNE COLE
A. L. WILDS

RECEIVED MARCH 28, 1939

1,2-DIARYLACETYLENE GLYCOLS. A NEW TYPE OF ENE-DIOL

Sir:

The isolation of the dienol I in solid form¹ suggested that an ene-diol such as 1,2-dimesitylacetylene glycol (II), being more highly conjugated,



might possess still greater stability. This has proved to be true. The ene-diol is formed by the action of the binary mixture, Mg + MgI₂,² on dimesityl diketone or 2,4,6-trimethylbenzoyl chloride.

(1) Fuson, Ross and McKeever, *THIS JOURNAL*, **61**, 414 (1939).

(2) Gomberg and Bachmann, *ibid.*, **49**, 236 (1927).

The ene-diol is a white solid (plates) which melts at 144–145° in a nitrogen-filled sealed tube.

Anal. Calcd. for C₂₀H₂₄O₂: C, 81.04; H, 8.16. Found: C, 81.02; H, 8.01.

It can be kept indefinitely in an atmosphere of dry nitrogen but when exposed to air autoxidizes rapidly even in the solid state, giving the corresponding benzil. The ene-diol rearranges to 2,4,6,2',4',6'-hexamethylbenzoin under the influence of hydrochloric acid or piperidine. It reduces Tollens' reagent as well as cupric acetate solution at 0°. It is immediately oxidized by sodium 2,6-dichlorobenzeneoneindophenol. The isomeric benzoin does not react with Tollens' reagent or cupric acetate solution in the cold nor with the indophenol even when heated.

2,4,6-Triethylbenzoyl chloride gives a similar but even more stable ene-diol when treated with the binary mixture.

These ene-diols are unique in that in them the ene-diol grouping is not conjugated with a carbonyl group.³ However, it is conjugated with two aromatic nuclei. This consideration suggested that the remarkable stability of the new ene-diols might be shared by their vinyls derived from ketones of the types RCO(CH=CH)_n-COR and RCO(C₆H₄)_nCOR. Evidence of this already has been brought forward by Lutz and Reveley,⁴ who report the existence in solution of an ene-diol obtained by the reduction of 1,2-di-(2,4,6-trimethylbenzoyl)-ethylene.

A detailed report of our work will be presented in the near future.

(3) See Barnes and Green, *ibid.*, **60**, 1549 (1938).

(4) Paper presented at the Baltimore meeting of the American Chemical Society, April 4, 1939.

UNIVERSITY OF ILLINOIS
URBANA, ILLINOIS

REYNOLD C. FUSON
JOSEPH CORSE

RECEIVED MARCH 23, 1939

PANTOTHENIC ACID AND THE FILTRATE (CHICK ANTI-DERMATITIS) FACTOR

Sir:

An extensive series of investigations on pantothenic acid, a factor stimulating the growth of yeast, has been conducted by Williams and co-workers, culminating in the preparation and elementary analysis of the calcium salt.¹ Properties so far described for the filtrate² (chick anti-derma-

(1) Williams, Weinstock, Rohrmann, Truesdail and Meyer, *THIS JOURNAL*, **61**, 454 (1939).

(2) (a) Lepkovsky and Jukes, *J. Biol. Chem.*, **114**, 109 (1936); (b) Jukes, *ibid.*, **117**, 11 (1937); (c) Woolley, Waisman, Mickelsen and Elvehjem, *ibid.*, **125**, 715 (1938).

titis) factor are in agreement with the properties of pantothenic acid.¹

A sample of calcium pantothenate was kindly furnished by Dr. R. J. Williams. Day-old chicks were placed on a normal diet for eight days, following which they were fed a heated diet^{2b} for ten days, at the end of which time incipient symptoms of dermatitis were apparent. The birds were then divided into groups and fed the supplements indicated in the table. Five chicks were used in each group.

TABLE I

Group	Supplement to 100 g. of heated diet	Av. weight (g.) of chicks at		No. of birds showing symptoms of dermatitis at 25 days
		18 days	25 days	
1	None	76	83	5
2	1.5 mg. Ca pantothenate prepn.	75	85	4
3	10 mg. Ca pantothenate prepn.	77	112	0
4	3 cc. rice bran extract (positive control diet)	75	110	0

The calcium pantothenate preparation was markedly active at the 10-mg. level. Since the rice bran extract furnished about 28 "units"^{2b} of filtrate (chick anti-dermatitis) factor per cc., a minimal activity of approximately 8400 "units" per gram was indicated for the calcium pantothenate preparation. Dr. Williams stated that the preparation contained about 1600 "pantothenic acid units" per gram, measured by yeast growth stimulation, fresh liver containing about 0.6 "unit" per gram. Previous experiments in this Laboratory have indicated fresh liver to contain about 3 "filtrate-factor units" per gram. Thus a ratio of approximately 5:1 exists between the yeast pantothenic acid "unit"¹ and the chick "filtrate-factor" unit^{2b} both in the case of the calcium pantothenate preparation and in the case of fresh liver.

Addendum.—After the preparation of this communication a copy of a manuscript by Woolley, Waisman and Elvehjem³ reporting that "the chick anti-dermatitis factor appears to be very similar in properties to pantothenic acid" was received in this division.

DIVISION OF POULTRY HUSBANDRY THOMAS H. JUKES
UNIVERSITY OF CALIFORNIA
DAVIS, CALIFORNIA

RECEIVED MARCH 20, 1939

(3) Woolley, Waisman and Elvehjem, *THIS JOURNAL*, **61**, 977 (1939).

POLAROGRAPHIC CURRENT-VOLTAGE CURVES WITH DROPPING AMALGAM ELECTRODES

Sir:

The writer has discovered that it is possible, by means of the polarographic technique,^{1,2} to obtain anodic current-voltage curves with dropping amalgam electrodes whose characteristics are very similar to the ordinary c. v. (current-voltage) curves obtained with the dropping mercury electrode. As far as the writer is aware, current-voltage curves with dropping amalgam electrodes heretofore have not been described in the literature.

Typical c. v. curves of a very dilute cadmium amalgam, obtained with a polarograph,^{1,2} are shown in Figs. 1 and 2. The curve in Fig. 1 was obtained with an approximately 0.01% cadmium

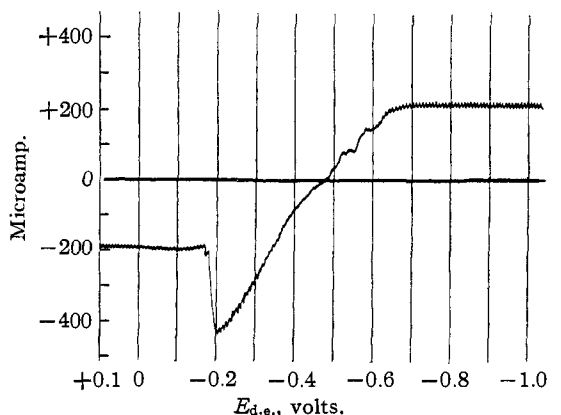


Fig. 1.—Current-voltage curve with dropping cadmium amalgam electrode.

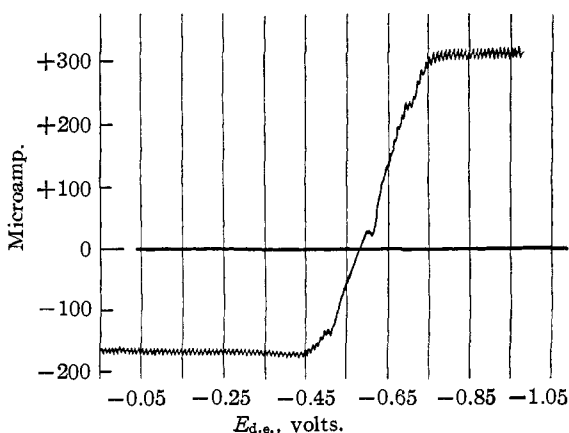


Fig. 2.—Elimination of the anodic maximum of cadmium amalgam by sodium methyl red.

(1) J. Heyrovsky, "Polarographie," in W. Bottger's "Die physikalischen Methoden der chemischen Analyse," Akad. Verlagsgesellschaft, Leipzig, 1936, Vol. II, pp. 260-322.

(2) I. M. Kolthoff and J. J. Lingane, *Chem. Rev.*, **24**, 1 (1939).

amalgam dropping into an air-free 0.1 *N* potassium chloride solution which was 0.04 *M* with respect to cadmium sulfate. The potential of the dropping electrode, referred to the saturated calomel electrode, $E_{d.e.}$, is plotted on the abscissa, and the corresponding current in microamperes on the ordinate. The horizontal line marks the rest point (zero current) of the recording galvanometer. The section of the curve above the galvanometer zero line (positive current) corresponds to the discharge of cadmium ions into the amalgam, $Cd^{++} + 2e + Hg \rightarrow Cd(Hg)$. The section of the curve below the galvanometer zero line (negative current) is due to the anodic dissolution of cadmium from the amalgam, $Cd(Hg) \rightarrow Cd^{++} + 2e + Hg$. The anodic section of the curve exhibits a prominent maximum, exactly similar to the maxima frequently obtained in the reduction of metal ions at the dropping mercury electrode, which is followed by a well-defined diffusion current whose magnitude is proportional to the amalgam concentration.

The curve in Fig. 2 was obtained in a similar way, except that 0.1 ml. of a 0.1% solution of sodium methyl red was added to 10 ml. of the solution. The addition of the methyl red completely eliminated the anodic maximum, and produced a very well-defined wave with a constant diffusion current. This effect of methyl red shows that the anodic maximum, like the common cathodic maxima,² is caused by phenomena on the solution side, and not the amalgam side, of the amalgam-solution interface.

The characteristics of these anodic c. v. curves with dropping amalgam electrodes are being further investigated, and a more detailed report will be submitted in the near future.

SCHOOL OF CHEMISTRY OF THE
INSTITUTE OF TECHNOLOGY
UNIVERSITY OF MINNESOTA
MINNEAPOLIS, MINN.

JAMES J. LINGANE

RECEIVED MARCH 10, 1939

KINETICS OF HYDROCARBON DECOMPOSITION

Sir:

I have to thank you for your courteous permission to call attention to the fact that, in his recent review of the Kinetics of Hydrocarbon Decomposition [*Chem. Rev.*, **22**, 311 (1938)] Professor Steacie has completely mis-stated our results and conclusions. We show that when one experiments with equilibrium mixtures of ethane, ethy-

lene, and hydrogen, instead of with the pure hydrocarbons, the effect of the changes represented by the equation



is eliminated. Professor Steacie's statement is exactly the opposite to this. Following the pyrolytic changes by means of exact analyses, which are not "unchecked," it is then found that the rates of disappearance of 2-carbon hydrocarbon is represented by the equation

$$-d(\text{2-carbon hydrocarbon})/dt = K(C_2H_6)(C_2H_4)$$

This conclusion results from nearly a hundred experiments with equilibrium mixtures, and can hardly be a matter of chance. The conclusion is that the time-determining step is a process involving one molecule of each of the hydrocarbons.

Our experiments do, indeed, differ from those of others, but because we alone work with equilibrium mixtures, and also take account of the fact that the formation of benzenoid condensation products is of importance equal to that of the formation of methane. This latter point has been generally ignored. In these experiments, contrary to Professor Steacie's statement, we observe no induction period, and the x/t graphs show no breaks. Initial temperature lag is of no importance, or is easily corrected for.

With pure ethane the rates of formation of methane and condensation products are self-accelerated, a fact which supports the conclusion which we draw from our experiments on the equilibrium mixtures. The rates of formation of these products are, however, somewhat faster than the rates calculated from the experiments with equilibrium mixtures, and the graphs show breaks, but not till a long time after the start, so that they cannot be accounted for by initial time lag. We cannot explain these phenomena, a fact which is hardly remarkable, considering the present position of our knowledge of chemical kinetics.

DEPARTMENT OF INORGANIC AND PHYSICAL CHEMISTRY
THE UNIVERSITY

BRISTOL 8, ENGLAND

MORRIS W. TRAVERS

RECEIVED FEBRUARY 6, 1939

NATURE AND PARTIAL SYNTHESIS OF THE CHICK ANTIDERMATITIS FACTOR

Sir:

The preparation of highly active concentrates of the chick antidermatitis factor has been de-

scribed [Woolley, *et al.*, *J. Biol. Chem.*, **125**, 715 (1938)]. Further investigation revealed that the activity of these concentrates is very readily destroyed by alkali. β -Alanine has been isolated from the alkali-inactivated concentrates. The acidic part of the alkali-inactivated concentrates can be reactivated by coupling with synthetic β -alanine in the following manner.

The alcohol-soluble barium salt fraction (Woolley, *et al.*) was dissolved in *N* sodium hydroxide and warmed for one hour. The solution was acidified and shaken with ethyl acetate, and the extracted material was acetylated with acetic anhydride. Volatile matter was removed under reduced pressure, and the residue was treated for one hour at room temperature with a large excess of SOCl_2 . After removal of the excess reagent under reduced pressure, the light brown, semi-solid residue was dissolved in dry pyridine, cooled in ice water, and slowly treated with an excess of β -alanine ethyl ester. The pyridine was removed under reduced pressure, and the residue was suspended in dilute hydrochloric acid (final pH of 2) and extracted with ethyl acetate. The extract was freed of solvent, and treated with cold, alcoholic sodium hydroxide in order to remove the acetyl and ester groups. After one hour the solution was carefully neutralized with alcoholic hydrochloric acid.

The β -alanine was isolated from the ethyl acetate extracted residue of the alkali-treated concentrate by continuous ether extraction for four days, extraction of the residual solution with butanol, and crystallization from the extract with

ethanol: yield, 9 mg. from 1300 g. of liver extract; m. p. 204–206°; found N, 15.8.

The assays of the untreated concentrate, the alkali-treated concentrate, and the above products are shown in Table I.

TABLE I

	Level fed, equiv. to liver extract	Av. gain in 4 wks. ^a	% of chicks showing symptoms
Untreated concentrate	10%	91, 106	0
NaOH treated	40%	34, ...	100
Synthesized mixture	40%	94, 95	0
β -Alanine	0.1% of ration	37, ...	100

^a Figures represent two independent runs.

The chick antidermatitis factor appears to be very similar in properties to pantothenic acid [Williams, *et al.*, *THIS JOURNAL* **60**, 2719 (1938); Snell, *et al.*, *ibid.*, **60**, 2825 (1938), and private communications]. Thus they both are heat and alkali labile hydroxy acids. The acetyl derivatives of both are heat stable and distill at approximately the same temperature and pressure. Furthermore, the solubilities of the free acid and of its metallic salts in various solvents are similar. Williams has shown that his preparations are composed of an hydroxy acid and β -alanine. The above experiments indicate that the chick antidermatitis factor is a hydroxy acid in amide linkage with β -alanine. Final proof of the identity of the two factors must await crystallization of the pure compound.

DEPARTMENT OF BIOCHEMISTRY
UNIVERSITY OF WISCONSIN
MADISON, WISCONSIN

D. W. WOOLLEY
HARRY A. WAISMAN
C. A. ELVEHEJEM

RECEIVED MARCH 3, 1939

NEW BOOKS

Atomphysik. I. Allgemeine Grundlagen. II. Theorie des Atombaus. (Atomic Physics. I. General Principles. II. Theories of Atomic Structure.) By Dr. KARL BECHERT and Dr. CHRISTIAN GERTHSEN, Professors in the University of Giessen. Walter de Gruyter and Company, Woyrschstrasse 13, Berlin W 35, Germany, 1938. 11 × 16 cm. 149 + 176 pp. 52 + 23 figs. Price, RM. 1.62 each.

These volumes, part of the series of books on chemical and physical subjects published by Göschen, attempt in three hundred small pages to cover the general field of atomic physics from an experimental and theoretical

standpoint. Such an undertaking is an ambitious one; it is not surprising that complete success does not result.

Volume I deals mainly with the experimental and theoretical background of modern physics: kinetic theory, electronic theory, beta-particles and cathode rays, the periodic system, radioactivity, collisions of the second kind, and the duality of matter. Volume II is principally an introduction to the quantum mechanical treatment of the atom beginning with the uncertainty relation and ending with a short excursion into the application of quantum mechanics to molecular spectra.

The presentation in general is clear, but the require-