[Contribution from the Department of Chemistry, Iowa State University, Ames, Iowa]

1,8-Additions to Troponoid Systems: A Novel Route to Substituted Cycloheptadienes[1]

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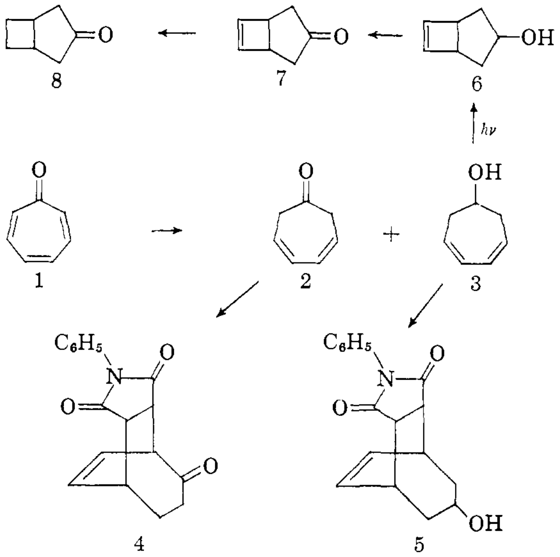
Lithium aluminum hydride reduction of tropone gives 3,5-cycloheptadienone and 3,5-cycloheptadienol. Similar reduction of γ-tropolone methyl ether gives 5-methoxy-2,4-cycloheptadienone, 5-methoxy-2,4-cycloheptadienol and 4-methoxy-3,5-cycloheptadienol. Methylmagnesium iodide adds to tropone giving 2-methyl-3,5-cycloheptadienone. Methylmagnesium iodide adds to γ-tropolone methyl ether giving 2-methyl-4-methoxy-3,5-cycloheptadienone and 7-methyl-4-methoxy-3,5-cycloheptadienone in a 9:1 ratio. These reactions proceed by 1,8-addition to the troponoid system and offer a synthetic approach to a variety of conjugated cycloheptadiene derivatives. This synthesis assumes added importance in the light of the photoisomerization of conjugated cycloheptadienes to bicyclo[3.2.0]heptenes.

We have studied the reactions of tropone and γ-tropolone methyl ether with lithium aluminum hydride and methylmagnesium iodide as part of our continuing investigation of the chemistry of troponoid systems.[3] These reactions proceed by a 1,8-addition mechanism and furnish substituted cycloheptadienes. This approach to the synthesis of substituted cycloheptadienes assumes considerable significance in the light of the recent discovery[4a,b,5] that a wide variety of conjugated cycloheptadienes undergo photoisomerization in good yield to bicyclo[3.2.0]heptenes.

Reduction of tropone (1) with lithium aluminum hydride for short periods of time gives 3,5-cycloheptadienone (2) and 3,5-cycloheptadienol (3) in a 2:3 ratio (yield 67%).



The 3,5-cycloheptadienone (2) shows infrared absorption at 5.84 μ and gives an N-phenylmaleimide adduct (4), m.p. 200–200.5°, in good agreement with the reported values.[6] Hydrogenation of 2 over platinum gives cycloheptanone. The 3,5-cycloheptadienol (3) shows an ultraviolet maximum at 241 mμ and gives an N-phenylmaleimide adduct (5), m.p. 185.5–187.0° (reported[6] 242 mμ and 185–188°). Hydrogenation of 3 requires two moles of hydrogen and gives cycloheptanol. Lithium aluminum hydride reduction of 2 gives 3. Irradiation of 3 gives a mixture of stereoisomeric alcohols (6) which can be oxidized to 7.[4b] Catalytic reduction of 7 gives the known ketone 8[4b] which has been compared directly and as the crystalline semicarbazone with an authentic specimen[7] provided by Dr. R. Srinivasan.

Reduction of γ-tropolone methyl ether (9) with lithium aluminum hydride gives a ketone (10, 44%) and a mixture of alcohols (11 and 12, 30%). The ketone (10, 328 mμ; 6.05μ) is hydrolyzed in dilute acid to 2-cyclohepten-1,5-dione (13) which can be reduced catalytically to cycloheptan-1,4-dione (14). Confirmation of the structure 10 was obtained by photoisomerization of 10 to 15[4b] which absorbs one mole of hydrogen over platinum giving tetrahydrophoto-γ-tropolone methyl ether (16)[4b] identical in infrared absorption and vapor phase chromatographic retention time with an authentic sample obtained by catalytic reduction of photo-γ-tropolone methyl ether (17).[3a] Lithium aluminum hydride reduction of 10 gave an alcohol (11) identical with one of the alcohols obtained in the reduction of γ-tropolone methyl ether (9). This alcohol is oxidized to 10 by manganese dioxide. Irradiation of 11 gives a photoisomer (18) which shows two olefinic protons as a complex multiplet at 3.85 τ in the nuclear magnetic resonance spectrum and which is stable to mild acid treatment. Treatment of the dienol 11 with dilute acid gives almost instantaneously 2,4-cycloheptadienone (19). The second alcohol obtained in the reduction of γ-tropolone methyl ether was not obtained in pure form; the isomeric alcohol (11) was always present. This alcohol is formulated as 12 on the basis of mechanistic considerations and the following evidence. Irradiation of 12 gives a photoisomer (20) which is hydrolyzed in dilute acid at room temperature to a cyclobutanone (21, 5.63μ). Treatment of 12 with dilute acid at room temperature does not give 2,4-cycloheptadienone directly as is the case with 11 but gives an intermediate (227 mμ) which is thought to be the ketoalcohol 22. When this solution is

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(1) A preliminary report of this work has been published, O. L. Chapman and D. J. Pasto, *Chemistry & Industry*, 54 (1961). Portions of this paper have been taken from a thesis submitted to the Graduate Faculty of Iowa State University by D. J. Pasto.

(2) National Institutes of Health Predoctoral Fellow, 1958–1960.

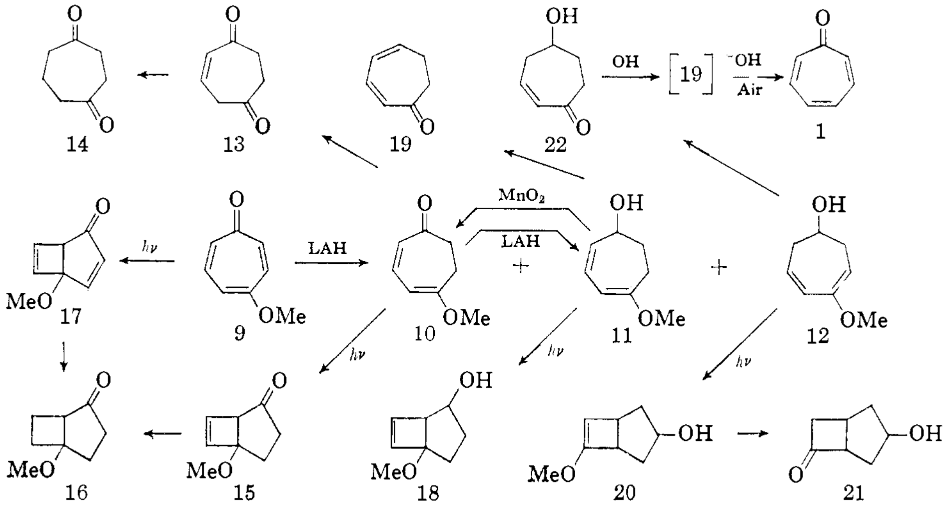
(3) For previous papers in this series see: (a) O. L. Chapman and D. J. Pasto, *J. Am. Chem. Soc.*, **82**, 3642 (1960); (b) O. L. Chapman and D. J. Pasto, *ibid.*, **81**, 3696 (1959).

(4) (a) O. L. Chapman and D. J. Pasto, *Chemistry & Industry*, 53 (1961); (b) O. L. Chapman, D. J. Pasto, W. G. Borden and A. A. Griswold, *J. Am. Chem. Soc.*, **84**, 1220 (1962).

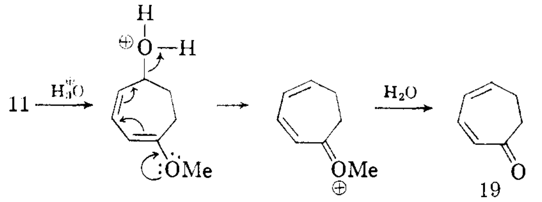
(5) W. G. Dauben and R. L. Cargill, *Tetrahedron*, **12**, 186 (1961).

(6) Isomerization to the conjugated dienone occurs before, or during, adduct formation; J. Meinwald, S. L. Emerman, N. C. Yang and G. Büchi, *J. Am. Chem. Soc.*, **77**, 4401 (1955).

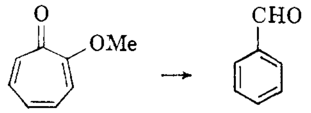
(7) S. Cremer and R. Srinivasan, *Tetrahedron Letters*, **No. 21**, 24 (1960).



made mildly basic and warmed, the 227 mμ absorption disappears rapidly, and the ultraviolet absorption characteristic of tropone (225, 227.5, 231, 293(sh) and 312 mμ) appears. This reaction probably involves base-catalyzed dehydration to 2,4-cycloheptadienone (19) which is known to be rapidly air-oxidized to tropone in alkaline solution.[8] The more facile dehydration of 11 to 2,4-cycloheptadienone is presumably due to assistance by the unshared electron pairs of the methoxyl oxygen in removal of the protonated allylic hydroxyl group.



Previous studies of the reactions of lithium aluminum hydride with monocyclic troponoid compounds have been confined to the α-tropolone methyl ethers.[9] The α-tropolone methyl ethers give predominantly products in which the troponoid ring has contracted to a benzenoid ring. α-Tropolone methyl ether (23), for instance, gives benzaldehyde on reduction with lithium aluminum hydride,[10] and in similar fashion 4-methyltropolone methyl ether and 6-methyltropolone methyl ether (24) give 3-methylbenzaldehyde and 3-methylbenzyl alcohol.[11] 6-Methyltropolone methyl ether (24) also gives 4-methyltropone on reduction with lithium aluminum hydride.[11] Mechanistically, all of the lithium aluminum hydride reductions of α-tropolone methyl ethers must involve initial hydride attack on the carbonyl group.[9] The reduction of tropone to 2 and 3 and the reduction of γ-tropolone methyl ether to 10, 11 and 12 thus are the first clearly defined examples of hydride attack on a troponoid ring.[12] These reductions can be conveniently rationalized as 1,8-additions of the metal hydride to the troponoid system. This addition is quite analogous to the addition of Grignard reagents to troponoid systems discussed below. It is interesting and instructive to inquire concerning the fate of the aluminum enolate initially formed, for the 1,8-addition in itself is not sufficient to account for the formation of 10 and 11 in the reduction of γ-tropolone methyl ether. It would not be surprising if 25, the product anticipated on the basis of a simple 1,8-addition, isomerized to 10 during work up, but this would not account for the formation of the alcohol 11. One possibility is that the aluminum enolate 26 equilibrates with the tautomer 27 which could rearrange to 28. An intramolecular rearrangement of 27 to 28 is reasonable sterically because of the geometry of the 3,5-cycloheptadien-



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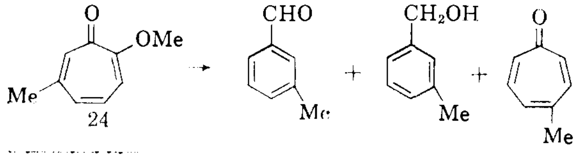

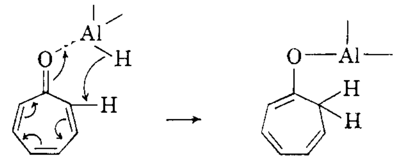

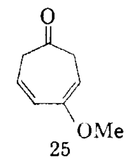

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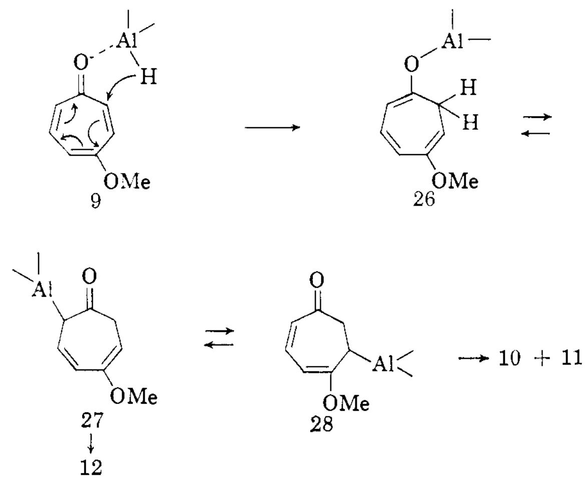
[8] E. E. van Tamelen and G. T. Hildahl, *J. Am. Chem. Soc.*, **78**, 4405 (1956).

[9] For a recent review see T. Nozoe, Chapter VII in D. Ginsberg (Editor), "Non-benzenoid Aromatic Compounds," Interscience Publishers, Inc., New York, N. Y., 1959.

[10] J. W. Cook, R. A. Raphael and A. I. Scott, *J. Chem. Soc.*, 4416 (1952).

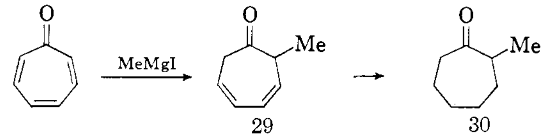
[11] P. Akroyd, R. D. Haworth and P. R. Jeffries, *ibid.*, 286 (1954)

[12] It has been suggested that lithium aluminum hydride reduction of 2,4,7-tribromotropone involves reduction of the troponoid ring (A. W. Johnson, A. Langemann and M. Tisler, *J. Chem. Soc.*, 1622 (1955)), but the structure of the product is not known.

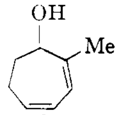


one ring. An intermolecular transfer of aluminum is also possible. Hydrolysis of 28 would yield 10 and reduction of 28 would lead to 11. Reduction of 27 would lead to 12. The observation that no 2,4-cycloheptadienone is formed in the reduction of tropone suggests that the driving force for the rearrangement of 27 to 28 is the resonance stabilization of the methoxy-dienone system in 28. Attack by hydride ion at the 2-position (shown above) should be strongly favored over attack at the 7-position (compare the attack of methylmagnesium iodide on 9 discussed below).

Tropone (1) reacts with methylmagnesium iodide in ether giving as the major product (50%) 2-methyl-3,5-cycloheptadienone (29, 217 mμ,[13] 5.85 μ).



Catalytic reduction of 29 requires two moles of hydrogen and gives 2-methylcycloheptanone (30) identical to an authentic sample obtained by alkylation of cycloheptanone. Lithium aluminum hydride reduction of 29 gives a product with analysis for $C_8H_{12}O$ and shows ultraviolet maxima at 241 and 247 mμ. This product undoubtedly is a mixture of isomeric alcohols. The 247 mμ maximum in the ultraviolet probably is due to the formation of the rearranged alcohol 31 as well as the expected alcohol 32. The significant observation in this



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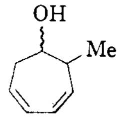

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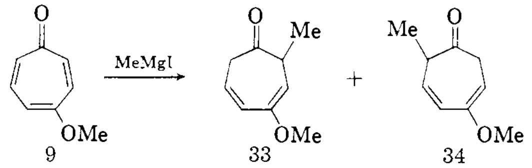
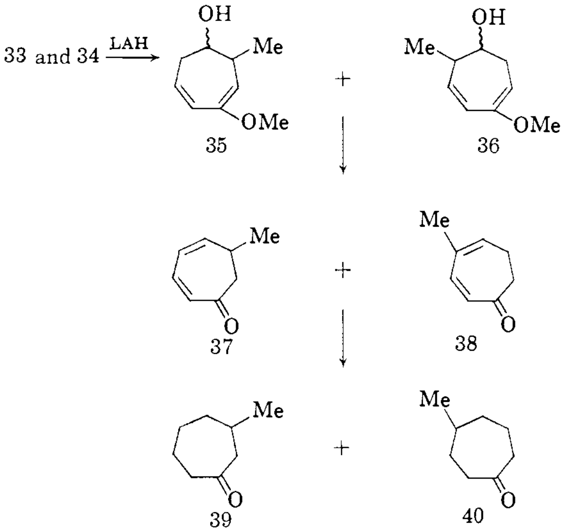
reduction is the return of the ultraviolet absorption maximum to a position characteristic of 1,3-cycloheptadienes.[14] Closs has recently reported[15] that methyllithium adds to tropone in a manner analogous to the addition of methylmagnesium iodide.

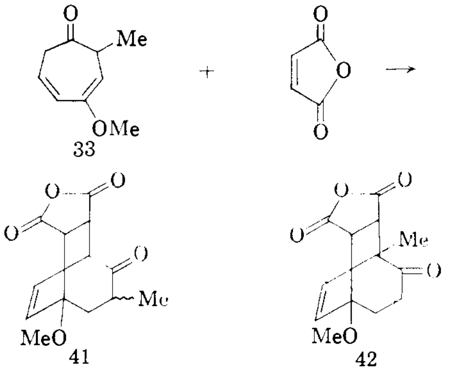
Treatment of γ-tropolone methyl ether (9) with methylmagnesium iodide in ether gives as the major product (45%) an apparently homogeneous ketone, $C_9H_{12}O_2$. Vapor phase chromatographic analysis of the product, however, showed the product to be a 9:1 mixture of two very similar ketones.



These ketones are formulated as 33 (predominant isomer) and 34 on the basis of the following evidence. Lithium aluminum hydride reduction of the ketone mixture gives a mixture of alcohols (35 and 36, 256 mμ) which on treatment with acid then base gives a mixture of methylcycloheptadienones (37 and 38, 293 mμ). Hydrogenation of the methylcycloheptadienone mixture gives 3-methylcycloheptanone (39) and 4-methylcycloheptanone (40) in a 6:1 ratio (analysis by vapor phase chromatography).



Maleic anhydride reacts with ketone 33 giving the adduct 41 which we could not induce to crystallize.



The adduct 41 does not give a benzal derivative when treated with base and benzaldehyde in accord with structures 33 and 41 for the ketone and its

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[13] This ultraviolet absorption is anomalous, but it is analogous to the absorption of 3,5-cycloheptadienone (see ref. 6). A possible explanation of this anomalous ultraviolet absorption has been advanced (see ref. 4b).

[14] Cycloheptadiene absorbs at 242 mμ in 95% ethanol.

[15] G. L. Closs and L. E. Closs, *J. Am. Chem. Soc.*, **83**, 599 (1961).

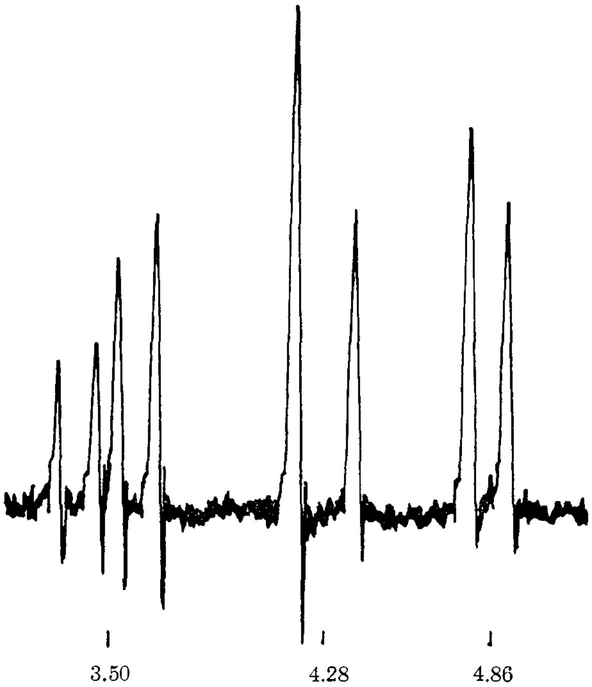
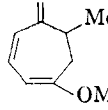


Fig. 1.—Sixty megacycle nuclear magnetic resonance spectrum showing the olefinic protons of 7-methyl-5-methoxy-2,4-cycloheptadienone (44). Peak locations are p.p.m. relative to tetramethylsilane (10 p.p.m.) in carbon tetrachloride.

adduct. The isomeric ketone 34 would lead to adduct 42 which should form a benzal derivative. The structure of the adduct is established by the following transformations. Hydrolysis of 41 in acid solution gives a crystalline diacid (43) without loss of carbon. This excludes the presence of an enol ether grouping (which would be present if 33 reacted without rearrangement to the conjugated dienone 44. The isomerization of 33 to 44 prior to, or during, adduct formation is strictly analogous to the isomerization of 3,5-cycloheptadienone to 2,4-cycloheptadienone in reaction with N-phenylmaleimide.[6,16] Treatment of diacid 43 with bromine in water gives a bromolactone which must be either 45 or 46.



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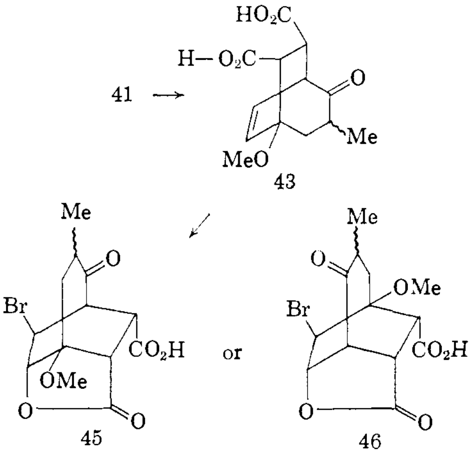
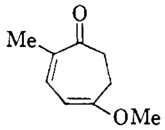


In either event the stereochemistry of the adduct 41 must be as shown. Brief treatment of ketone 33 with base leads quantitatively to the conjugated isomer 44. The conjugated isomer is obtained directly from the reaction mixture if the alumina is too basic or the contact time on alumina is too long. The ultraviolet spectrum of 44 (331 mμ) is almost identical to that of 10 furnishing additional evidence that 33 is the major product since the conjugated ketone 47 expected from 34 should absorb at appreciably longer wave length. Unequivocal evidence for the structures 33 and 44 is provided by the nuclear magnetic resonance spectrum of 44 which shows the presence of three olefinic protons. The splitting pattern of these olefinic protons (Fig. 1) is that expected for 44 and is identical to that of the olefinic protons of 10.



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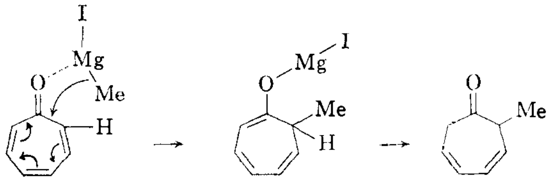
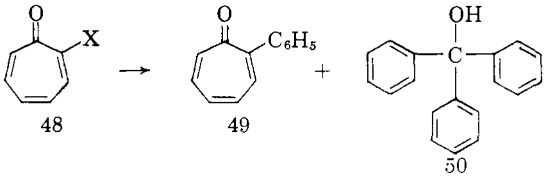
The addition of methylmagnesium iodide to tropone and γ-tropolone methyl ether are conveniently rationalized on the basis of a 1,8-addition mechanism analogous to that proposed to account for the replacement of substituents in the 2-position of α-tropolone methyl ethers and 2-halotropones by organometallic reagents.[9] α-Tropolone methyl ether (48, X = OMe)[17,18] and 2-halotropones (48, X = halogen)[18] react with phenylmagnesium bromide or phenyllithium giving 2-phenyltropone (49) and triphenylcarbinol (50). It is possible to formulate two mechanisms by which replacement of the C-2 substituent might occur.[9] The inter-





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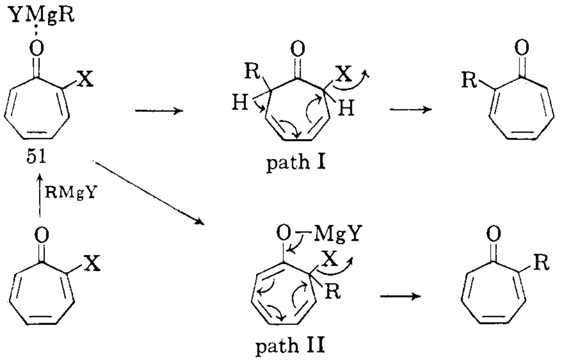
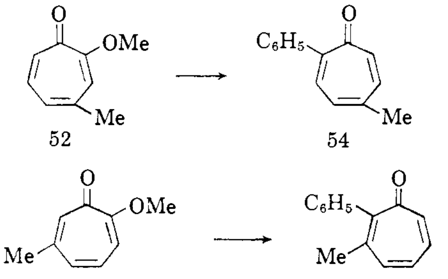
[16] It is surprising that adduct formation with a 2,4-cycloheptadienone is apparently more rapid than adduct formation with a 3,5-cycloheptadienone. The reason for this apparent anomaly may be the fact that 2,4-cycloheptadienone has all trigonal atoms in the same plane while the conjugated diene system in a 3,5-cycloheptadiene is badly distorted.

[17] T. Nozoe, T. Mukai and I. Murata, *Proc. Japan Acad.*, **28**, 142 (1952); T. Nozoe, S. Seto, T. Ikemi and T. Satô, *ibid.*, **28**, 413 (1952); T. Nozoe, T. Mukai and J. Minegishi, *ibid.*, **27**, 419 (1951).

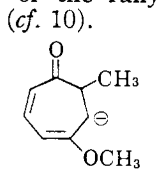
[18] W. von E. Doering and C. F. Hiskey, *J. Am. Chem. Soc.*, **74**, 5688 (1952).



mediate complex 51 might undergo 1,8-addition of the organometallic reagent on either side of the carbonyl group. Either addition can lead to the observed product, but these mechanistic paths are clearly distinguishable in appropriately substituted tropones. Haworth has shown[19] in elegant fashion that 4-methyltropolone methyl ether (52) and 6-methyltropolone methyl ether (53) give 54 and 55,


52 54 53 55

respectively. These results are in accord with reaction *via* mechanistic path I. It is not clear how general this mechanism is in the reactions of troponoid systems with organometallic reagents. Nucleophiles other than organometallic reagents react with 2-substituted tropones (replacing the group X) by both paths I and II.[9] The ring contracted product 50 is clearly the result of attack on the carbonyl group.[9,20] Distinction between paths I and II becomes meaningless in troponoid compounds which lack a good leaving group in the 2-position. 1,8-Addition on one side of the carbonyl group or the other becomes simply a matter of electronic preference. The importance of electronic factors in governing the site of nucleophilic attack by organometallic reagents on the troponoid nucleus is clearly illustrated in the preferential formation of 33 over 34. The preferential formation of 33 over 34 probably results from the greater stability of the transition state 56 leading to 33 compared to the transition state 57 which leads to 34. The greater stability of 56 arises from the retention of the fully conjugated methoxydienone system (*cf.* 10).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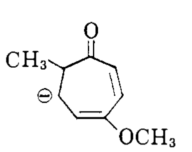
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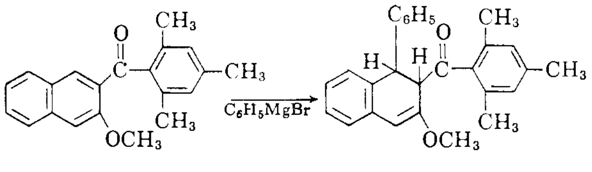
The products obtained in the addition of methylmagnesium iodide to tropone and γ-tropolone methyl ether amount to trapping the hydroaromatic intermediates postulated to account for the products observed in reactions proceeding by path I and lend strong support to the suggestion that these reactions are 1,8-additions. It is interesting to note that Fuson and co-workers in their investigations of the Grignard reactions of highly hindered aryl ketones have found several examples of replacement of *o*-methoxyl groups[21,22] and have observed an addition of phenylmagnesium bromide to a naphthalene ring[22] which is particularly interesting in comparison with the addition of Grignard reagents to tropone and γ-tropolone methyl ether.



The addition of lithium aluminum hydride and Grignard reagents to troponoid systems which are not substituted in the 2-position offers a new approach to the synthesis of conjugated cycloheptadienes. This synthesis coupled with the photoisomerization of conjugated cycloheptadienes to bicyclo[3.2.0]hept-6-enes[4] provides a synthetic entry to a variety of interesting and useful bicyclo[3.2.0]heptane derivatives.

Acknowledgment.—The authors acknowledge with appreciation the financial support of this investigation by a research grant (CY-4253) from the Cancer Division of the National Institutes of Health, Public Health Service.

Experimental

Lithium Aluminum Hydride Reduction of Tropone.—A solution of tropone (1.5 g.) in 10 ml. of ether was added slowly to a stirred suspension of 0.5 g. of lithium aluminum hydride in 20 ml. of ether. The reaction mixture was stirred at room temperature for 10 min. and then carefully decomposed by addition of moist sodium sulfate. After filtration and drying over sodium sulfate, removal of the ether under reduced pressure gave 1.00 g. (67%) of a yellow liquid which showed significant infrared maxima at 2.78, 2.82, 5.84 and 6.27 μ. Analysis of the crude product by vapor phase chromatography on a Theed[23] column showed the presence of two components with retention times of 4.2 min. (2, 40%) and 8.3 min. (3, 60%). Separation of the components by preparative scale vapor phase chromatography gave 3,5-cycloheptadienone (2, 5.83 and 6.27 μ) and 3,5-cycloheptadienol (3, 2.76, 2.80 and 6.20μ; 241 mμ).

Reaction of 2 and 3 with N-Phenylmaleimide.—A solution of 400 mg. of the crude product from the lithium aluminum hydride reduction of tropone and 640 mg. of N-phenylmaleimide in 3 ml. of anhydrous benzene was refluxed for 6 days. The reaction mixture was chromatographed directly on a 30 × 1 cm. alumina column. Elution with benzene–chloroform (3:1) gave adduct 4, m.p. 200–200.5° (reported[6] 199–202°), and elution with pure chloroform gave adduct 5, m.p. 185.5–187.0° (reported[6] 185–188°).

Reduction of 3,5-Cycloheptadienone to Cycloheptanone.—A solution of 3,5-cycloheptadienone (2) in methanol containing prereduced platinum oxide was permitted to absorb two equivalents of hydrogen. Evaporation of the methanol after filtration gave a colorless residue which on treatment with 2,4-dinitrophenylhydrazine in ethanolic acid gave cycloheptanone 2,4-dinitrophenylhydrazone, m.p.

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[19] R. D. Haworth and P. B. Tinker, *J. Chem. Soc.*, 911 (1955).

[20] W. von E. Doering and D. B. Denney, *J. Am. Chem. Soc.*, **77**, 4619 (1955).

[21] R. C. Fuson and S. B. Speck, *ibid.*, **64**, 2446 (1942).

[22] R. C. Fuson and V. Tullio, *ibid.*, **74**, 1624 (1952).

[23] Tetrakis-(β-hydroxyethyl)-ethylenediamine on Celite.

143.5–144.5°. A mixed melting point with cycloheptanone 2,4-dinitrophenylhydrazone showed no depression.

Hydrogenation of 3,5-Cycloheptadienol.—A solution of 118 mg. of crude 3,5-cycloheptadienol in 10 ml. of cyclohexane containing 25 mg. of prereduced 10% palladium-on-carbon catalyst was permitted to absorb hydrogen. Hydrogen uptake ceased after absorption of 40.4 ml. (S.T.P., 84% of the theoretical). Evaporation of the solvent after removal of the catalyst by filtration gave cycloheptanol which showed the same retention on a diethylene glycol succinate v.p.c. column alone and mixed with authentic cycloheptanol obtained by lithium aluminum hydride reduction of cycloheptanone. The product on treatment with 3,5-dinitrobenzoyl chloride gave cycloheptyl 3,5-dinitrobenzoate, m.p. 80° (reported[24] 79°).

Reduction of 3,5-Cycloheptadienone to 3,5-Cycloheptadienol.—An ethereal solution of crude 3,5-cycloheptadienone was added to excess lithium aluminum hydride suspended in ether, and the reaction mixture was stirred at room temperature for a few minutes. The reaction was quenched by addition of moist sodium sulfate. After filtration and drying over magnesium sulfate, removal of the ether under reduced pressure gave a colorless residue which was identical in infrared and ultraviolet absorption to authentic 3,5-cycloheptadienol.

Lithium Aluminum Hydride Reduction of γ-Tropolone Methyl Ether.—A solution of γ-tropolone methyl ether (2.0 g., 0.0147 mole) in 25 ml. of ether was added to a suspension of lithium aluminum hydride (1.12 g., 0.0294 mole) in 25 ml. of ether. The reaction mixture was stirred for 10 min. at room temperature, and the excess reagent was decomposed by cautious addition of distilled water. The ether layer was decanted, and the aqueous layer was extracted twice with 15-ml. portions of ether. The ether extracts were combined and dried over sodium sulfate. Evaporation of the ether under reduced pressure gave a pale yellow liquid which showed infrared maxima at 2.77, 6.05, 6.16 and 6.39 μ. The crude product was chromatographed on a 35 × 1 cm. alumina column. Elution with pentane–benzene gave 0.88 g. (44%) of a ketonic product which after molecular distillation showed infrared maxima at 6.05, 6.16 and 6.39 μ and $\lambda_{\max}^{95\%\ \mathrm{EtOH}}$ 328 mμ (8,500).

Anal. Calcd. for $C_8H_{10}O_2$: C, 69.55; H, 7.30. Found: C, 69.36; H, 7.41.

Elution with benzene, benzene–chloroform and chloroform gave a mixture of two alcohols (11 and 12, 0.61 g., 30%). Vapor phase chromatographic separation of the alcohol mixture on a 1-meter Ucon LB-550X grease–firebrick column gave one pure alcohol (11) identical in infrared absorption and vapor phase chromatographic retention time with a sample of 5-methoxy-2,4-cycloheptadienol obtained by lithium aluminum hydride reduction of 10 and a second alcohol (12) which was still contaminated with 11.

Conversion of 5-Methoxy-2,4-cycloheptadienone (10) **to Cycloheptan-1,4-dione** (14) **via 13.**—A solution of 5-methoxy-2,4-cycloheptadienone (7, 30 mg.) in 1 ml. of water was treated with 4 drops of 10 *N* sulfuric acid. The solution was extracted twice with chloroform. Removal of the chloroform after drying over anhydrous magnesium sulfate gave a residue (13) which showed infrared absorption at 5.85, 6.00 and 6.16 μ and ultraviolet maxima at 233 mμ (5,400) and 297 mμ (1,000). Hydrogenation of this residue in methanol (10 ml.) over platinum required 1.0 mole of hydrogen (based on 10). The catalyst was removed by filtration, and the methanol was removed under reduced pressure. The residue thus obtained was treated with 2,4-dinitrophenylhydrazine in ethanolic acid. After two recrystallizations from ethanol-nitrobenzene the 2,4-dinitrophenylhydrazone thus obtained showed melting point and mixed melting point with authentic cycloheptan-1,4-dione bis-2,4-dinitrophenylhydrazone 241–245°.[25]

5-Methoxy-2,4-cycloheptadienol.—A solution of 170 mg. (0.0012 mole) of 5-methoxy-2,4-cycloheptadienone in 5 ml. of anhydrous ether was added over a 5-minute period to a stirred solution of 100 mg. (0.0026 mole) of lithium aluminum hydride in 20 ml. of anhydrous ether. After 5 minutes stirring, the reaction mixture was hydrolyzed by careful addition of water. The solids were filtered off, and the ether filtrate was dried over anhydrous magnesium sulfate. The ether was removed under reduced pressure leaving 140 mg. of a pale yellow liquid. The residue was molecularly distilled giving 120 mg. of 5-methoxy-2,4-cycloheptadienol which showed maxima in the infrared at 3.00, 6.11, 6.22, 7.98, 8.34, 8.54, 9.66, 11.10, 13.23 and 14.05 μ. The ultraviolet absorption spectrum showed $\lambda_{\max}^{95\%\ \mathrm{EtOH}}$ 256 mμ (7,590).

Anal. Calcd. for $C_8H_{12}O_2$: C, 68.54; H, 8.63. Found: C, 68.69; H, 8.99.

Manganese Dioxide Oxidation of 11.—A solution of 5-methoxy-2,4-cycloheptadienol (11, 50 mg., $\lambda_{\max}^{95\%\mathrm{EtOH}}$ 256 mμ) in 10 ml. of chloroform was stirred at room temperature with 0.50 g. of activated manganese dioxide. Aliquots were removed periodically and evaporated to dryness. The residue was dissolved in 95% ethanol, and the ultraviolet absorption was measured. The absorption maximum at 256 mμ (characteristic of 11) slowly disappeared, and a maximum at 328 mμ (characteristic of 5-methoxy-2,4-cycloheptadienone, 10) appeared. The reaction was approximately 50% complete after 84 hr.

5-Methoxybicyclo[3.2.0]hept-6-ene-2-ol (18).—A solution of 46 mg. of 5-methoxy-2,4-cycloheptadienol in 60 ml. of anhydrous ether in a quartz vessel with a reflux condenser was irradiated for 60 min. with a General Electric UA-3 mercury arc lamp. The ether was removed under reduced pressure, and the residue was molecularly distilled. The infrared absorption spectrum in carbon tetrachloride showed maxima at 2.78, 2.91, 3.40, 3.54, 6.90, 7.68 and 8.50 μ.

Anal. Calcd. for $C_8H_{12}O_2$: C, 68.54; H, 8.63. Found: C, 68.46; H, 8.84.

Acid Hydrolysis of 5-Methoxy-2,4-cycloheptadienol.—A standard solution of 16 mg. of 5-methoxy-2,4-cycloheptadienol in 5 ml. of 95% ethanol was prepared. A 1-ml. aliquot was successively diluted with 0.1194 *N* sulfuric acid to 2.28 × 10^{-5} *M*. The ultraviolet absorption spectrum of this solution showed $\lambda_{\max}^{H_2SO_4}$ 296 mμ (4,890).

Conversion of 4-Methoxy-3,5-cycloheptadienol (12) **to 3-Hydroxy-6-ketobicyclo[3.2.0]heptane** (21) *via* **20.**—A solution of 4-methoxy-3,5-cycloheptadienol (12, 133 mg.) in 50 ml. of ether was irradiated in a quartz vessel with a General Electric UA-3 mercury arc lamp until the extinction at 255 mμ was 5% of the initial value (68 min.). The ether was removed under reduced pressure. The residue (20) was treated with 1 ml. of 0.1 *N* sulfuric acid. After 5 min. at room temperature the residue had completely dissolved in the acid solution. This solution was extracted with ether. The residue obtained by evaporation of the ether after drying over sodium sulfate was molecularly distilled (70° (0.2 mm.)) giving 21 as a colorless, viscous liquid which showed intense infrared absorption at 2.95 and 5.63 μ.

Conversion of 4-Methoxy-3,5-cycloheptadienol (12) **to Tropone.**—A solution of 4-methoxy-3,5-cycloheptadienol (12, 6.9 mg.) in 25 ml. of 95% ethanol was prepared. A 1-ml. aliquot of this solution was acidified with 4 drops of 10 *N* sulfuric acid and heated at 80° for 5 min. The ultraviolet of this solution showed maxima at 227 mμ (ϵ 5,600, due to ketoalcohol 22) and 292 mμ (1,400, due to 2,4-cycloheptadienone). This solution was neutralized, and 2 drops of 30% sodium hydroxide solution was added. The basic solution was heated at 80° for 10 min. This solution after acidification with sulfuric acid showed maxima at 225, 227.5, 231, 239(shoulder) and 312 mμ characteristic of tropone.[26] The estimated yield of tropone based on the absorbance at 227.5 mμ was 35%.

Reaction of Methylmagnesium Iodide with Tropone.—A solution of 3.0 g. (0.0283 mole) of tropone in 30 ml. of anhydrous ether was slowly added to an 0.0423 *M* ethereal solution of methylmagnesium iodide. Each drop of tropone solution caused the formation of a bright yellow solid that immediately dissolved. After addition (15 min.) the yellow solution was stirred at room temperature for 10 min. Water (4 ml.) was added very slowly to the reaction mixture. The ether layer was decanted from the solids. The ether solution was dried over anhydrous sodium sulfate, and the ether was removed under reduced pressure, leaving 2.01 g. of a red-brown liquid. The liquid residue was molecularly distilled giving 1.8 g. of 2-methyl-3,5-cycloheptadienone. The infrared absorption spectrum showed maxima at 3.31, 3.37,

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(24) L. N. Owen and G. S. Saharia, *J. Chem. Soc.*, 2582 (1953).

(25) A. C. Cope, T. A. Liss and G. W. Wood, *J. Am. Chem. Soc.*, **79**, 6287 (1957).

(26) W. von E. Doering and F. L. Detert, *ibid.*, **73**, 877 (1951); H. J. Dauben, Jr., and H. J. Ringold, *ibid.*, **73**, 876 (1951).

5.86, 6.29, 6.89, 9.73, 9.88 and 14.50μ. The ultraviolet absorption spectrum showed $\lambda_{\max}^{95\%\ \text{EtOH}}$ 217 and 298 mμ.

Anal. Calcd. for $C_8H_{10}O$: C, 78.65; H, 8.25. Found: C, 78.87; H, 8.39.

2-Methylcycloheptanone.—A solution of 65.4 mg. of 2-methyl-3,5-cycloheptadienone in 15 ml. of *n*-pentane was permitted to absorb 2 molar equivalents of hydrogen using 10% palladium-on-charcoal as catalyst. The catalyst was removed by filtration, and the *n*-pentane was removed under reduced pressure. Molecular distillation of the residue gave a colorless liquid which showed infrared absorption maxima at 3.42, 3.49 and 5.89 μ. Treatment of the product with a cold solution of 2,4-dinitrophenylhydrazine in ethanolic acid gave the 2,4-dinitrophenylhydrazone. Recrystallization of the 2,4-dinitrophenylhydrazone from ethanol–water gave bright yellow needles which upon admixture with authentic 2,4-dinitrophenylhydrazone of 2-methylcycloheptanone showed no depression in melting point and melted at 120–121.5° (reported[27] 121–122°).

2-Methyl-3,5-cycloheptadienol.—To a stirred solution of 0.1 g. (0.0026 mole) of lithium aluminum hydride in 20 ml. of anhydrous ether was added a solution of 0.2 g. (0.0016 mole) of 2-methyl-3,5-cycloheptadienone in 5 ml. of anhydrous ether. After stirring for 5 min. the reaction mixture was hydrolyzed carefully with water. The solids were removed by filtration, and the filtrate was dried over anhydrous sodium sulfate. The ether was removed under reduced pressure leaving 0.17 g. of yellow liquid. The liquid was molecularly distilled, giving 0.145 g. of a pale yellow liquid. The infrared absorption spectrum showed significant maxima at 2.99, 6.22 and 14.61μ. The ultraviolet absorption spectrum showed $\lambda_{\max}^{95\%\ \text{EtOH}}$ 241 mμ and 247 mμ.

Anal. Calcd. for $C_8H_{12}O$: C, 77.37; H, 9.74. Found: C, 77.32; H, 10.00.

2-Methyl-4-methoxy-3,5-cycloheptadienone (33).—A solution of γ-tropolone methyl ether (9, 2.0 g.) in 20 ml. of ether was added slowly to a vigorously stirred solution of methylmagnesium iodide prepared from 2 g. of magnesium and 3.12 g. of methyl iodide in 25 ml. of ether. The reaction mixture was stirred at room temperature for 1 hr. and then decomposed by careful addition of distilled water. The ether layer was decanted, and the aqueous solution was extracted twice with ether. Evaporation of the ether under reduced pressure after drying over sodium sulfate gave 1.45 g. of a dark yellow residue which showed infrared absorption at 2.92, 5.85, 6.10, 6.15 and 7.27μ. Extraction of the aqueous solution with methylene chloride gave an additional 0.1 g. of crude product. The crude product was chromatographed on a 20 × 1 cm. alumina column. Elution with benzene–pentane gave 900 mg. (45%) of 2-methyl-4-methoxy-3,5-cycloheptadienone (33). Distillation through a microdistillation head gave a pale yellow liquid, b.p. 58–60° (0.2 mm.), $n^{22}\text{D}$ 1.5188, which showed infrared absorption at 5.85 (strong), 6.09 (med.), 6.15 (med.) and 7.27μ (med.). Vapor phase chromatographic analysis of the ketone on a 1 meter Theed[23] column showed the presence of 10% of the isomeric ketone 34.

Anal. Calcd. for $C_9H_{12}O_2$: C, 71.03; H, 7.95. Found: C, 71.28; H, 8.28.

Conversion of 33 and 34 to 39 and 40.—An ethereal solution of 750 mg. of 33 and 34 (9:1 by v.p.c. analysis) was added to a suspension of excess lithium aluminum hydride in ether. The solution was stirred for 1 hr. at room temperature. The reaction mixture was hydrolyzed with moist sodium sulfate, and the solution was filtered. Removal of the ether after drying over sodium sulfate gave the alcohols 35 and 38, $\lambda_{\max}^{95\%\ \text{EtOH}}$ 256 mμ (5,600).

Acid hydrolysis of 500 mg. of the alcohol mixture in 0.5 ml. of methanol, 0.2 ml. of water and 0.01 ml. of concentrated hydrochloric acid at room temperature for 10 min. gave, after removal of the solvent under reduced pressure, a mixture of ketones (6.03 μ; 228, 293 mμ).

The crude ketone, mixture in 20 ml. of methanol was hydrogenated over prereduced Adams catalyst. Evaporation of the methanol after removal of the catalyst gave a mixture of saturated ketones (39 and 40, 5.88 μ). Vapor phase chromatographic analysis of the mixture showed the ratio of 3-methylcycloheptanone (39) to 4-methylcycloheptanone (40) to be 6:1. The ketones were identified by direct comparison of retention times with authentic samples of 39 and 40.

Preparation of 41.– A solution of 2-methyl-4-methoxy-3,5-cycloheptadienone (33, 0.35 g.) and maleic anhydride (0.25 g.) in 2 ml. of benzene was refluxed for 6 days. The benzene was removed in a stream of air leaving a dark, viscous residue. Sublimation (130° (0.1 mm.)) gave the adduct 41 as a pale yellow glass which could not be induced to crystallize (5.36, 5.60 and 5.85 μ). A portion of the adduct (100 mg.) was dissolved in boiling water, and 1 drop of 10 *N* sulfuric acid was added. This solution when cooled deposited a mass of tan crystals. Recrystallization from water gave the diacid 43 as colorless needles, m.p. 153–153.5°.

Anal. Calcd. for $C_{13}H_{16}O_6$: C, 58.20; H, 6.01. Found: C, 58.25; H, 6.11.

The adduct (41, 55 mg.) in 0.5 ml. of ethanol was treated with excess benzaldehyde and 1 drop of 30% sodium hydroxide. Dilution with water and extraction gave only unchanged adduct.

A solution of the adduct (41, 40 mg.) in boiling water was treated with bromine until a slight excess remained. This solution was extracted with chloroform. Removal of the chloroform after drying over sodium sulfate gave the bromolactone (45 or 46; 5.58, 5.79 and 5.82 μ).

Isomerization of 33 to 7-Methyl-5-methoxy-2,4-cycloheptadienone (44).—A solution of 2-methyl-4-methoxy-3,5-cycloheptadienone (33, 20 mg.) in 0.5 ml. of ethanol was treated with 1 ml. of 1.0 *N* sodium hydroxide, and the solution was swirled for 2 min. The solution was extracted twice with ether, and the ether extract was dried over sodium sulfate. Removal of the ether gave the crude conjugated ketone 44. Molecular distillation gave 44, $\lambda_{\max}^{95\%\text{EtOH}}$ 331 mμ (7,160).

Anal. Calcd. for $C_9H_{12}O_2$: C, 71.03; H, 7.95. Found: C, 71.30; H, 8.00.

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[27] R. Jacquier and H. Christol, *Bull. soc. chim. France*, 600 (1957).