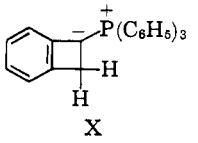
probably arise from ethanolysis of the bis-ylide IV to mono-ylide X by small amounts of ethanol present in the reaction mixture,[9] followed by reaction of the mono-ylide X with benzaldehyde. Studies are now underway to evaluate this hypothesis.



X

Aside from the analysis and expected *trans* product from the Wittig reaction, the structure of V rests on the following spectral and degradative evidence. The ultraviolet spectrum shows λ_{max}^{EtOH} 335 mμ (log ϵ 4.21), 332.5 (4.22), 307 (4.01), 282 (4.26), 238.5 (4.35), and 232.5 (4.39). The n.m.r. spectrum in CCl_4 has an absorption singlet at 6.72 (H_a), 7.41 (close multiplet, H_b), and 7.65 p.p.m. (broad multiplet, H_c) in integrated ratio of 1:2:5, respectively. The infrared spectrum shows λ_{max}^{Nujol} 6.07 (double bond), 12.92 and 13.10 (*ortho*-disubstituted benzene ring), and 13.64 and 14.32 μ (monosubstituted benzene rings).[10] Prolonged periodate–permanganate oxidation of compound V in dioxane–benzene–water[11] produced benzoic acid (60%) and phthalic acid (50%), both identical with authentic samples, as well as a small amount of phthalic anhydride (infrared).

Work continues on the reactions and properties of the compounds III and IV and the synthesis of other benzocyclobutenes containing electron-withdrawing substituents and will be reported in due course.

Acknowledgments.—The support of the National Science Foundation, Grant No. G18902, is gratefully acknowledged. We sincerely appreciate helpful discussions with Dr. D. G. Farnum, Dr. A. William Johnson, and Dr. Jerrold Meinwald.

(9) See M. Grayson and P. T. Keough, *J. Am. Chem. Soc.*, **82**, 3919 (1960), for examples of similar reactions.

(10) A referee has suggested the alternate *cis,trans* structure for V, since, on steric grounds, such a structure should be more stable. We feel, however, that the *trans,trans* stereochemistry is correct for the following reasons: (i) the *cis,trans* isomer should exhibit a doublet in the n.m.r. since the two vinylic hydrogens would have different chemical environments, but we obtain only a low-field singlet, and (ii) in a case where all three isomers were obtained (when IV is treated with *p*-nitrobenzaldehyde) the *trans,trans* isomer is obtained in greatest yield and has a singlet in the n.m.r., while the *cis,trans* product exhibits a doublet in the vinylic region of the n.m.r. However, *cis,cis* stereochemistry cannot be ruled out.

(11) R. U. Lemieux and E. von Rudloff, *Can. J. Chem.*, **33**, 1701, 1710, (1955); E. von Rudloff, *ibid.*, **33**, 1714 (1955).

(12) N.S.F. Predoctoral Research Fellow, 1963–1964; N.S.F. Predoctoral Cooperative Fellow, 1964–1965.

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RECEIVED AUGUST 17, 1964

Methyl Migration in the Reaction of Alkyl- and Acylmanganese Carbonyls

Sir:

One aspect of the so-called insertion reaction[1] of $CH_3Mn(CO)_5$ which has not received much attention is the mechanism by which the acetyl group is formed in reaction 1, where L is a nucleophile.

$$CH_3Mn(CO)_5 + L \longrightarrow CH_3COM\,n(CO)_4L \quad (1)$$

The two likely mechanisms are (a) insertion of a molecule of CO, previously bonded to the manganese, between the methyl group and the manganese, and (b) migration of the methyl group onto one of the terminal CO molecules. Although in the case of $CH_3Mn(CO)_5$ it is difficult to distinguish between the two mechanisms, in the case of a complex of the type *trans*-$CH_3Mn(CO)_4Z$, where Z is some ligand other than CO, reaction 2 can be used for this purpose. If this reaction proceeds

$$trans\text{-}CH_3Mn(CO)_4Z + CO \longrightarrow CH_3COMn(CO)_4Z \quad (2)$$

by carbonyl insertion, the product will be *trans*-$CH_3COMn(CO)_4Z$, whereas if it proceeds by methyl migration the *cis* isomer will be formed.

Since by the law of microscopic reversibility, the reverse of this process must proceed by the same mechanism as the forward reaction, one can equally well study reaction 3. A *trans* product would in-

$$trans\text{-}CH_3COMn(CO)_4Z \longrightarrow CH_3Mn(CO)_4Z + CO \quad (3)$$

dicate the reverse of carbonyl insertion, a *cis* product methyl migration (see Fig. 1).

We have studied the reactions of *trans*-$CH_3COMn(CO)_4P(Ph)_3$ (where Ph = C_6H_5), which we have found to be the initial product of the reaction of $CH_3Mn(CO)_5$ and $P(Ph)_3$ in either diethyl ether or tetrahydrofuran. The method of isolating this complex and the assignment of the *trans* structure were very kindly given to us prior to publication.[2]

The compound was prepared by treating equimolar amounts of $CH_3Mn(CO)_5$ and $P(Ph)_3$ in ether at 10° for 24 hr. under nitrogen and then evaporating to near dryness under a stream of nitrogen. The yellow crystals isolated had a melting point (98°) and an infrared spectrum in hexane solution (terminal C–O stretching frequencies 2066, 1995, and 1959 cm.$^{-1}$; acetyl C–O stretching frequency 1631 cm.$^{-1}$) identical with those reported by Kraihanzel and Cotton.[2]

We found that, at 25° in hexane or tetrahydrofuran solution, *trans*-$CH_3COMn(CO)_4P(Ph)_3$ was converted to a new compound, which was isolated by removing the solvent and recrystallizing from chloroform–ethanol. Yellow crystals (m.p. 110°) were obtained. The infrared spectrum in hexane solution (terminal C–O stretching frequencies 2055, 1983, 1968, and 1939 cm.$^{-1}$; no acetyl C–O stretching frequency) and analysis of this compound (*Anal.* Calcd. for $CH_3Mn(CO)_4P(Ph)_3$: C, 62.16; H, 4.08. Found: C, 62.07; H, 4.07) showed it to be $CH_3Mn(CO)_4P(Ph)_3$, previously prepared by a different method by Hieber, *et al.*,[3] who report an infrared spectrum for their sample which is virtually identical with that given above. We consider, in agreement with Kraihanzel and Cotton,[2] that the infrared spectrum (which is very similar to that reported[3] for the compounds *cis*-$Mn(CO)_4XP(Ph)_3$, where X = Cl, Br, or I) shows that this compound is *cis*-$CH_3Mn(CO)_4P(Ph)_3$.

The simplest mechanism for the formation of *cis*-$CH_3Mn(CO)_4P(Ph)_3$ from *trans*-$CH_3COMn(CO)_4P(Ph)_3$

(1) References to previous work in this field are given in R. J. Mawby, F. Basolo, and R. G. Pearson, *J. Am. Chem. Soc.*, **86**, 3994 (1964).

(2) C. S. Kraihanzel and F. A. Cotton, private communication.

(3) W. Hieber, G. Faulhaber and F. Theubert, *Z. anorg. allgem. Chem.*, **314**, 125 (1962).

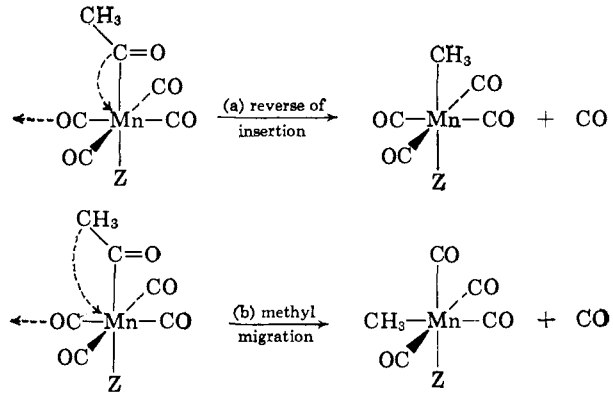

Fig. 1.—Decarbonylation of *trans*-$CH_3COMn(CO)_4Z$: (a) by reverse of insertion, (b) by methyl migration.

is by methyl migration (see Fig. 1, Z = $P(Ph)_3$). This would require that the rate of disappearance of the acetyl band in *trans*-$CH_3COMn(CO)_4P(Ph)_3$ be equal to the rate of change of the arrangement of terminal C–O stretching frequencies from that for *trans*-$CH_3COMn(CO)_4P(Ph)_3$ to that for *cis*-$CH_3Mn(CO)_4P(Ph)_3$. Since previous work[1] on the related reaction shown in eq. 1 had shown that in *n*-hexane the formation of intermediates, which could complicate kinetics and make a decision on a mechanism more difficult, was avoided, *n*-hexane was used as the solvent for the present work.

The reactions were followed by thermostating solutions of *trans*-$CH_3COMn(CO)_4P(Ph)_3$ in dry *n*-hexane under nitrogen. Samples were withdrawn at intervals and their spectra recorded in 1-mm. cells on a Beckman IR9 spectrophotometer. Solution concentrations were 0.6×10^{-2} *M* for following changes in terminal C–O stretching frequencies, and 1.5×10^{-2} *M* for following the disappearance of the acetyl C–O band.

The change from the terminal C–O frequencies of *trans*-$CH_3COMn(CO)_4P(Ph)_3$ to the arrangement for *cis*-$CH_3Mn(CO)_4P(Ph)_3$, as calculated from the rate of appearance of the bands in the product at 2055 and 1983 cm.$^{-1}$, was a first-order process with a rate constant of $3.83\ (\pm 0.05) \times 10^{-5}$ sec.$^{-1}$. The disappearance of the acetyl band of *trans*-$CH_3COMn(CO)_4P(Ph)_3$ was also a first-order process with a rate constant of $3.71\ (\pm 0.08) \times 10^{-5}$ sec.$^{-1}$.

The agreement between these two figures is good evidence for the direct conversion of *trans*-$CH_3COMn(CO)_4P(Ph)_3$ to *cis*-$CH_3Mn(CO)_4P(Ph)_3$ by methyl migration (see Fig. 1, Z = $P(Ph)_3$).

It is possible to devise more complicated mechanisms, involving two or more steps, one of which is rate controlling and the others very rapid, which are compatible with our kinetic results. However, we regard methyl migration as the simplest and by far the most likely mechanism for this reaction. This is believed to be the first real evidence for such a migration in these systems.[4]

We have also shown that a solution of *cis*-$CH_3Mn(CO)_4P(Ph)_3$ in tetrahydrofuran is reconverted, by storing under CO, to *trans*-$CH_3COMn(CO)_4P(Ph)_3$.

(4) Similar results have since been obtained by us in tetrahydrofuran solution, the rate constant obtained by either method being $2.70\ (\pm 0.07) \times 10^{-5}$ sec.$^{-1}$. Our results in this solvent show that the sample of $CH_3COMn(CO)_4P(Ph)_3$, whose isolation was referred to in an earier publication,[1] was in fact a mixture of *cis*-$CH_3Mn(CO)_4P(Ph)_3$ and *trans*-$CH_3COMn(CO)_4P(Ph)_3$ in which the former compound predominated. There is no evidence for the existence of *cis*-$CH_3COMn(CO)_4P(Ph)_3$.

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RECEIVED SEPTEMBER 11, 1964

New Lincomycin-Related Antibiotics

Sir:

Chemical studies[1] have elucidated the structure of lincomycin[2-6] (Ia). We now report the isolation and the structure of four new lincomycin-related antibiotics designated U-21,699, U-11,921, U-11,973, and U-20,943. Antibiotic U-21,699 normally occurs in lincomycin fermentations, while the production of U-11,921, U-11,973, and U-20,943 is induced by addition of DL-ethionine, methyl α-thiolincosaminide (IIa), and ethyl α-thiolincosaminide (IIb), respectively, to fermentation media of *S. lincolnensis*. The antibiotics were recovered by adsorption on carbon followed by elution with aqueous acetone and crystallization as hydrochloride salts.

Antibiotic U-21,699 (Ib) hydrochloride, $C_{17}H_{32}N_2O_6S \cdot HCl \cdot 0.5H_2O$,[7] $[\alpha]^{25}D$ +147°, contains one $-NCH_3$, one $-SCH_3$, two $C-CH_3$, and one basic function, pK_a' 7.68. Infrared absorptions (3400, 1690, and 1590 cm.$^{-1}$) indicated OH, NH, and amide functions. The n.m.r.[8,9] spectrum of Ib is very similar to that of Ia, except that it shows eight hydrogens in the 30–90-c.p.s. region, while the spectrum of Ia shows ten hydrogens in the same area. Both display the doublet at 67 and 75 c.p.s. (3H) assigned to the CH_3-CHO grouping present in methyl α-thiolincosaminide (IIa) and a triplet at 45, 52, and 59 c.p.s. (3H) assigned to the CH_3CH_2- of the side chain on the hygric acid nucleus (IIIa). This triplet, along with two hydrogens in the $-CH_2-$ region, is indicative of an ethyl group replacing the propyl group of lincomycin. Thus, Ib represents the structure of U-21,699. This conclusion was substantiated by hydrazinolysis of U-21,699 affording authentic methyl α-thiolincosaminide (IIa), and the hydrazide of a new amino acid which was hydrolyzed to the crystalline hydrochloride $C_8H_{15}NO_2 \cdot HCl$ (IIIb). Infrared spectra and the positive rotational shift at lower pH suggested an α-L-amino acid.

The n.m.r. spectra of IIIa and IIIb differ only in the area from 40 to 120 c.p.s. in that IIIa has a triplet

(1) H. Hoeksema, B. Bannister, R. D. Birkenmeyer, F. A. MacKellar, F. Kagan, B. J. Magerlein, W. Schroeder, G. Slomp, and R. R. Herr, *J. Am. Chem. Soc.*, **86**, 4423 (1964).

(2) Lincocin is the trademark of The Upjohn Company for lincomycin hydrochloride.

(3) D. J. Mason, A. Dietz, and C. DeBoer, *Antimicrobial Agents Chemotherapy*, 554 (1962).

(4) R. R. Herr and M. E. Bergy, *ibid.*, 560 (1962).

(5) L. J. Hanka, D. J. Mason, M. R. Burch, and R. W. Treick, *ibid.*, 565 (1962).

(6) C. N. Lewis, H. W. Clapp, and J. E. Grady, *ibid.*, 570 (1962).

(7) Analytical values for all the compounds described in this paper were consistent with the indicated formulas.

(8) Spectra were calibrated in c.p.s. units at 60 Mc., downfield from internal sodium 2,2-dimethyl-2-silapentane-5-sulfonate. Spectra were observed with a Varian A-60 spectrometer on solutions (*ca.* 0.4 ml., *ca.* 0.25 *M*) of the compounds in deuterium oxide.

(9) The helpful discussions with Messrs. F. A. MacKellar and J. F. Zieserl are gratefully acknowledged.