determination of dihydrostreptomycin,[10,17] hydroxystreptomycin,[18] and mannosidostreptomycin.[19]

The configurational determination of the asymmetry of the streptidine ring in streptomycin yields the same result (*i.e.*, R at C-4) as that recently determined chemically[16] and by the cuprammonium method[13] for the 2-deoxystreptamine ring of the neomycins,[13,16] paromomycins,[13] and kanamycins.[13] Thus these two vital components of a number of powerful antibiotics may have stereochemically similar biogenetic precursors.

Acknowledgment.—This investigation was supported in part by research grant No. G-6041 from the National Science Foundation.

(17) R. L. Peck, C. E. Hoffhine, Jr., and K. Folkers, *J. Am. Chem. Soc.*, **68**, 1390 (1946).

(18) F. H. Stodola, O. L. Shotwell, A. M. Borud, R. G. Benedict, and A. C. Riley, Jr., *ibid.*, **73**, 2290 (1951).

(19) J. Fried and H. E. Stavely, *ibid.*, **74**, 5461 (1952).

(20) National Science Foundation Cooperative Graduate Fellow, 1960–1962.

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Reactions of Organolithium Compounds and Diphenylacetylene

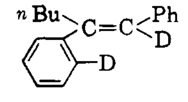
Sir:

The literature contains little information concerning the reaction between organolithium compounds and noncarbonyl, conjugated acetylenes. In contrast Grignard reagents are generally unreactive toward simple nonterminal alkynes[1] even under forcing conditions.

We find that diphenylacetylene and organolithium compounds react to form addition and/or metalation products or a dimer depending upon the choice of organolithium compound and conditions.

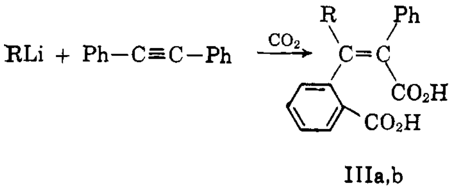
n-Butyllithium and diphenylacetylene do not react in pentane solution over a period of several hours, whereas the same compounds react in ethyl ether (24 hr., 30°) to give after hydrolysis, in addition to recovered starting material, a 40% yield of *trans*-α-*n*-butylstilbene, b.p. 143–144° (0.4 mm.) $\lambda\lambda_{max}$ 225 mμ (ϵ 5200), 268 mμ (ϵ 16,200). *Anal.* Calcd. for $C_{18}H_{20}$: C, 91.47; H, 8.53; mol. wt., 236. Found: C, 91.27; H, 8.63; mol. wt., 232. The *trans* nature of the product (single peak from v.p.c.) was demonstrated by photoisomerization using a Hanovia mercury arc lamp and isolating by means of preparative scale v.p.c. the new component which appears to the extent of approximately 24% after 72 hr. of illumination. The new component *cis*-α-*n*-butylstilbene had $\lambda\lambda_{max}$ 222 mμ (ϵ 13,000), 257 mμ (ϵ 10,900). In addition to having the expected shorter wave length maximum in the ultraviolet, the new compound (*cis*) displays olefinic proton resonance at 3.62 τ in contrast to the unisomerized compound (*trans*) in which olefinic proton resonance occurs at 3.36 τ. That the higher-field olefinic proton resonance is characteristic of the *cis* isomer in this sort of compound has been pointed out by Curtin, Gruen, and Shoulders.[2]

In order to demonstrate the existence of an olefinic organolithium intermediate, the *n*-butyllithium–diphenylacetylene reaction mixture was treated with deuterium oxide. The deuterated product showed no proton resonance in the 3.3 to 3.6 τ region, but, in addition, the deuterium content indicated that two protons had been exchanged, and the integrated n.m.r. spectrum revealed that one of the exchanged protons was from an aromatic ring. Based on the results of carbonation experiments (see below) the structure of the dideuterated adduct is I.



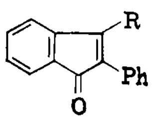
I

If diphenylacetylene in ethyl ether is treated with either ethyllithium or *n*-butyllithium, one obtains (after carbonation) in about 15% yield each a neutral (orange or red) ketone (II) and a dicarboxylic acid (III) besides recovered starting material.



IIIa,b

a, R = *n*-C_4H_9
b, R = C_2H_5



IIa,b

The structures of the 2-phenyl-3-alkylindones were confirmed by comparison with authentic samples synthesized according to published procedures.[3] The dicarboxylic acid structures III [IIIa, m.p. 176–177°. *Anal.* Calcd. for $C_{18}H_{18}(COOH)_2$: C, 74.05; H, 6.21; neut. equiv., 162. Found: C, 74.35; H, 6.45; neut. equiv., 166. IIIb, m.p. 191–192°: *Anal.* Calcd. for $C_{16}H_{14}(COOH)_2$: C, 72.96; H, 5.44; neut. equiv., 148. Found: C, 73.13; H, 5.48; neut. equiv., 148] are in accord with what one would expect on the basis of the indone products. Further structural elucidation was provided by converting IIIa to its dimethyl ester (IV), b.p. 162° (0.2 mm.) [*Anal.* Calcd. for $C_{18}H_{18}(COOCH_3)_2$: C, 74.98; H, 6.86; mol. wt., 352. Found: C, 75.20; H, 6.90; mol. wt., 349], using diazomethane. The n.m.r. spectrum of the ester shows two methyl singlets at 6.17 and 6.78 τ. The n.m.r. spectra of both the acid IIIa (in dioxane) and the dimethyl ester IV indicate eight aromatic protons in the region 2.6 to 2.7 τ and another single aromatic proton at a lower field in the 2.0 τ region, the latter being split into a doublet having coupling constants of 7–10 c.p.s. Both the chemical shift and the coupling constant are of the correct magnitude for an aromatic proton *ortho* to a —COO— group.[4] Because the integrated intensity of this low-field proton indicates only one hydrogen *ortho* to the —COO— group, the —COO— group must in turn be *ortho* to the olefinic bond.

The formation of the acids (III) and the indones (II) is most readily explained in terms of an intermediate (V) arising from metalation of the aromatic ring and ad-

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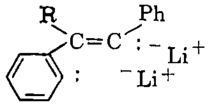
(1) (a) M. S. Kharasch and O. Reinmuth, "Grignard Reactions of Nonmetallic Substances," Prentice Hall, New York, N. Y., 1954; (b) for a recent exception see the unusual trimerization and tetramerization reactions of diphenylacetylene and phenylmagnesium bromide: M. Tsutsui, *Chem. Ind.* (London), 780 (1962).

(2) D. Y. Curtin, H. Gruen, and B. A. Shoulders, *Chem. Ind.* (London), 1205 (1958).

(3) R. L. Frank, H. Eklund, J. W. Reiliter, C. R. Vanneman, and A. N. Wennerberg, *J. Am. Chem. Soc.*, **66**, 1 (1944). 2-Phenyl-3-*n*-butylindone (IIa) is not reported in the literature. We have obtained this compound as a slightly impure high boiling red liquid. The 2,4-dinitrophenylhydrazone of this compound, m.p. 176–178°, correct anal., was identical with the 2,4-dinitrophenylhydrazone obtained from the red liquid indone prepared in a similar manner to the general method described in this reference.

(4) P. L. Corio and B. P. Dailey, *ibid.*, **78**, 3043 (1956). See also L. M. Jackman, "Applications of Nuclear Magnetic Resonance Spectroscopy in Organic Chemistry," Pergamon Press, New York, N. Y., 1959, p. 85.



dition of RLi to the triple bond. *ortho*-Metalation of benzene rings containing substituents which are inductively electron withdrawing is a well known phenomenon,[5] and the inductive electron-withdrawing effect of the triple bond is apparent in the increased acidity of a number of acetylenic carboxylic acids in comparison to their saturated analogs.[6] The dicarboxylic acids (III) are assigned the *trans* structure on the basis of the *trans* structure of the hydrolysis product from *n*-butyllithium and diphenylacetylene, in addition to the fact that the yield of indone, which requires a *trans* stereochemistry, may be increased by bubbling carbon dioxide through the reaction mixture, in contrast to our ordinary procedure of decanting onto a large excess of solid carbon dioxide. The *trans* nature of the products does not necessarily reflect the initial mode of addition of the *n*-butyllithium to the triple bond. Curtin and Koehl[7] have shown that even at 2° in ether–benzene, *cis*-stilbenzyllithium is completely isomerized to *trans*-stilbenzyllithium in 30 min. In the present investigation, our olefinic lithium compounds remained in ethyl ether solution many hours. The situation in this case is more complicated, however, since we obtain a dilithium intermediate. Indeed, there seems to be some special stability to this dilithium compound (II), inasmuch as we recover after carbonation only starting material and products arising from V, nothing from a monolithium compound. The implications of this fact are being investigated.

In contrast to ethyl- and *n*-butyllithium, we find, in agreement with a recent report,[8] that phenyllithium and diphenylacetylene give only triphenylacrylic acid (11%).

A still different course of reaction occurs between *t*-butyllithium and diphenylacetylene in ligroin (40 to 70°, 13 hr.). After hydrolysis, 1,2,3,4-tetraphenylbutadiene (30%) and *trans*-stilbene (5%) are isolated. The former compound was identified by comparison with an authentic sample prepared by the action of lithium metal on diphenylacetylene.[9] The lithium–diphenylacetylene reaction may very well proceed by dimerization of the diphenylacetylene anion radical, and a strong possibility exists that at least a portion of the *t*-butyllithium and diphenylacetylene reaction proceeds by an anion-radical intermediate. In accord with this the reaction mixture displays on e.s.r. signal having no fine structure. The formation of radical anions from *n*-butyllithium and a number of aromatic compounds has recently been reported.[10] *t*-Butyllithium would be expected to be an even better electron donor, since the process would presumably[11] involve the conversion of an unstable tertiary carbanion-like compound to a tertiary radical.[12]

Acknowledgment.—We wish to thank Professor Gordon Tollin of this Department for help in obtaining the e.s.r. spectra and also to thank the Socony-Mobil Oil Co. for generous support of this research.

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[5] H. Gilman, *Org. Reactions*, **8**, 258 (1954).

[6] C. K. Ingold, "Structure and Mechanism in Organic Chemistry," Cornell University Press, Ithaca, N. Y., 1953, pp. 735–736.

[7] D. Y. Curtin and W. J. Koehl, Jr., *J. Am. Chem. Soc.*, **84**, 1967 (1962).

[8] J. J. Eisch and W. C. Kaska, *ibid.*, **84**, 1501 (1962).

[9] L. I. Smith and H. H. Hoehn, *ibid.*, **63**, 1184 (1941).

[10] H. W. Brown and R. C. Jones, *J. Chem. Phys.*, **36**, 2809 (1962).

[11] For papers indicating that the order of carbanion stability is *pri.* > *sec.* > *tert.*, see: (a) P. D. Bartlett, S. Friedman, and M. Stiles, *J. Am. Chem. Soc.*, **75**, 1771 (1953); (b) A. Schriesheim and C. A. Rowe, Jr., *ibid.*, **84**, 3160 (1962); (c) D. E. Applequist and D. F. O'Brien, *ibid.*, **85**, 743 (1963); (d) R. E. Dessy and R. M. Salinger, Abstracts of Papers, 145th National Meeting of the American Chemical Society, New York, N. Y., Sept., 1963; p. 56Q.

[12] P. D. Bartlett and S. J. Tauber have found a different course of reaction when *t*-butyllithium and diphenylacetylene react in ethyl ether at −30°. One of the products (after carbonation) is β-*t*-butyl-α,β-diphenylacrylic acid. We thank Professor Bartlett for communicating this information prior to publication.

Racemization of an Optically Active Fluorosilane without Displacement of Fluoride Ion: Evidence for an Expanded-Octet Mechanism

Sir:

Previous studies have revealed highly stereospecific reactions of many optically active organosilicon compounds containing the α-naphthylphenylmethylsilyl group.[1-3] More recently, stereospecific reactions of optically active organogermanium compounds containing the same organic substituents have been reported.[4] In all such cases of reactions proceeding with pure, or nearly pure, inversion or retention of configuration, it is clear that the mechanism may or may not involve expanded-octet intermediates (penta- or hexacovalent silicon intermediates). However, it is equally clear that the mechanisms of such stereospecific reactions cannot involve fast equilibrium formation of an expanded-octet (addition) complex which returns to starting materials with inversion of configuration at a rate which approximates or exceeds its decomposition to products. Thus, for stereospecific reactions, mechanism 1, in which k_{inv} approximates k_{ret} and exceeds k_2, cannot obtain if the optical purity of R_3Si^*X is high.

$$\begin{tikzcd}
(+)R_3Si^*Y + (X)_n \arrow[r, shift left, "k_1"] & R_3Si^*Y(X)_n \arrow[l, shift left, "k_{\text{ret}}"] \arrow[r, "k_2"] \arrow[d, shift left, "k_{\text{inv}}"] & R_3Si^*X \quad (1) \\
 & (-)R_3Si^*Y + (X)_n \arrow[u, shift left, "k_1"] &
\end{tikzcd}$$

Stereospecific reactions of R_3Si^*F (α-napthylphenylmethylfluorosilane), which cannot involve mechanism 1 having $k_{\text{inv}} \sim k_{\text{ret}} > k_2$, are known. Reaction 2 proceeds with inversion of configuration[1] and 3 with retention of configuration.[5]

$$(+)R_3Si^*F + LiAlH_4 \xrightarrow{\text{ether}} (-)R_3Si^*H \qquad (2)$$

$$(+)R_3Si^*F + i\text{-}PrLi \xrightarrow{\text{pentane}} (+)R_3Si^*\text{-}i\text{-}Pr \qquad (3)$$

Nevertheless, the high bond energy of Si–F (*ca.* 130 kcal./mole), the high electronegativity of fluorine, and its small size, as well as the existence of the stable SiF_6^{2-} ion, suggested to us that mechanism 1 might obtain for R_3Si^*F under certain conditions which would also lead to the relationship $k_{\text{inv}} > k_2$.

In the racemization experiments described below, the product in all cases is pure racemic fluorosilane. Macroscopic formation of a substitution product does not take place, and involvement of a substitution product in an equilibrium unfavorable to its isolation is ruled out by studies described later. Thus, it is clear that the rate of racemization greatly exceeds the rate of displacement of fluoride ion. In fact, the latter does not occur at all during the time required for complete racemization, under the designated conditions.

In sum, our observations and conclusions lead to the

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[1] L. H. Sommer, C. L. Frye, M. C. Musolf, G. A. Parker, P. G. Rodewald, K. W. Michael, Y. Okaya, and R. Pepinsky, *J. Am. Chem. Soc.*, **83**, 2210 (1961).

[2] L. H. Sommer, *Angew. Chem. Intern. Ed. Engl.*, **1**, 143 (1962).

[3] A. G. Brook and C. M. Warner, *Tetrahedron Letters*, **18**, 815 (1962).

[4] A. G. Brook and G. J. D. Peddle, *J. Am. Chem. Soc.*, **85**, 2338 (1963).

[5] L. H. Sommer, P. G. Rodewald, and G. A. Parker, *Tetrahedron Letters*, **18**, 821 (1962).