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CONJUGATE ADDITION OF ORGANOLITHIUM REAGENTS TO DIPHENYLCYCLOPROPENONE

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Very little is known concerning the behavior of cyclopropenones toward organometallic reagents.[2,3] In fact, no reports have appeared regarding the conjugate attack of such reagents on cyclopropenones.[4,5] We wish to report here the formation of α,β,β-triphenylpropionic acid (7a) and α,β,γ,γ-tetraphenylbutyric acid (7b) as a result of the conjugate addition of phenyllithium and diphenylmethyllithium, respectively, to diphenylcyclopropenone (1).

Normal addition[6] of 1 in THF to a solution of phenyllithium[7] (slight excess) in THF at 0° under nitrogen produced a red-brown solution. Hydrolysis of the reaction mixture with saturated aqueous KH_2PO_4 afforded the known α,β,β-triphenylpropionic acid (7a)[8] in approximately 18% yield[9] after recrystallization from cyclohexane, mp 220-221° (lit.[8] mp 221.5-222°) ν_{max}^{KBr} (cm^{-1}) 3450-2400 (s, broad), 1700 (s), 1605 (m), 1590 (m), 1500 (s), 1455 (s), and 1420 (m); nmr ($CDCl_3$, δ) 10.5 (1H, singlet), 6.9-7.5 (15H, multiplet), and 4.50 (2H, AB quartet, J = 12.5 Hz). A minor amount of a red crystalline solid (approximately 10%)[9] was also isolated by Florisil chromatography (benzene:hexane 1:1) of the neutral residue and purified by recrystallization from cyclohexane. It was identified as 2,3-diphenylindenone (9a), mp 151-153° (lit.[10] mp 152-153°) by direct comparison with an authentic sample.[11]

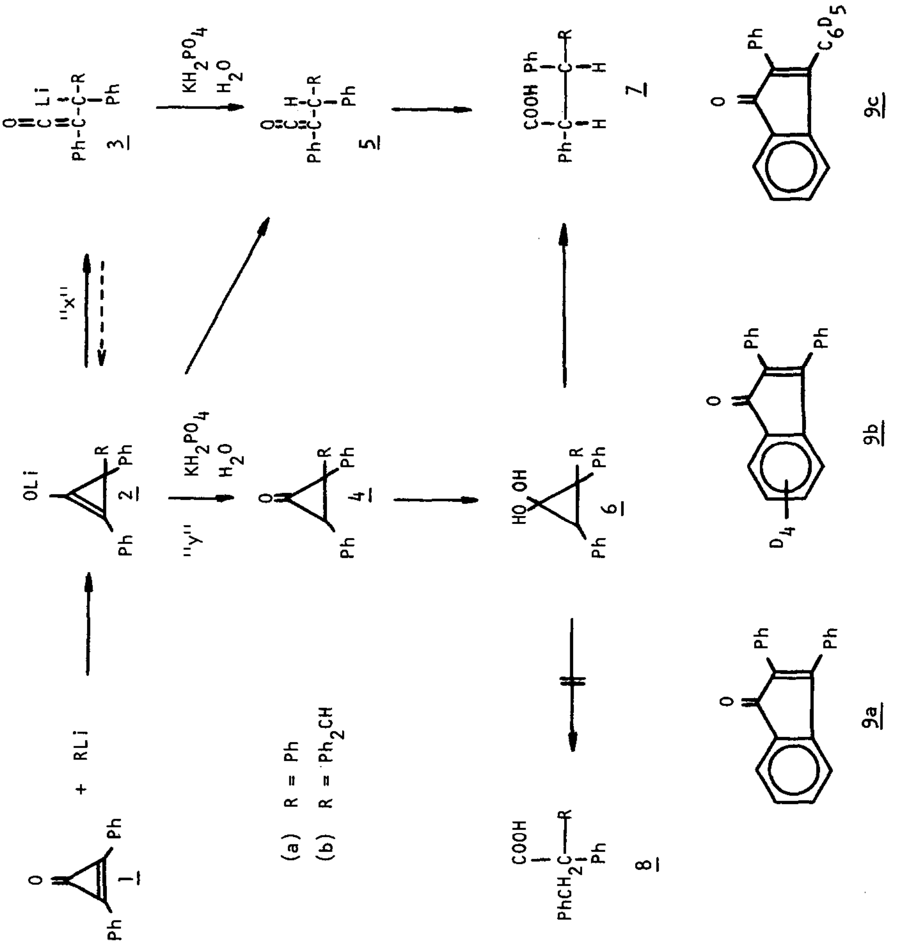
Similarly, the addition of 1 in THF to a solution of diphenylmethyllithium[12] in THF at 0° under nitrogen followed by hydrolysis as above afforded in addition to an unidentified carbonyl compound a mixture of carboxylic acids in approximately 70% yield, identified as *erythro* and *threo*- α,β,γ,γ-tetraphenylbutyric acid (7b). The higher melting epimer[13] (mp 199-200°), isolated by fractional recrystallization from benzene-cyclohexane, exhibited the following microanalytical and spectral data: *Anal*. Calcd for $C_{28}H_{24}O_2$: C, 85.68;

H, 6.16; Found: C, 85.84; H, 6.12; ν_{max}^{KBr} (cm^{-1}) 3500-2400 (s, broad), 1705 (s), 1600 (m), 1590 (w), 1495 (m), and 1450 (m); λ_{max}^{EtOH} 260 mμ (ε 840); nmr ($CDCl_3$, δ) 11.1 (1H, singlet), 6.7-7.7 (20H, complex), and 3.9-4.9 (3H, eight line ABC pattern). Finally, the erythro and threo acids 8b were synthesized unambiguously via the Michael addition of diphenylmethyllithium to α-phenylcinnamonitrile followed by hydrolysis of the erythro- and threo- α,β,γ,γ-tetraphenylbutyronitriles with either potassium hydroxide in refluxing ethylene glycol or a refluxing mixture of aqueous sulfuric and glacial acetic acids.[14]

The production of carboxylic acids 7a and 7b requires initial conjugate addition of phenyllithium and diphenylmethyllithium to the carbon-carbon double bond of 1. On mechanistic grounds indenone 9a, an oxidation product, could arise via attack of phenyllithium on the carbonyl carbon of 1 or via conjugate addition to 1. The use of pentadeuterophenyllithium[15] clearly establishes that indenone 9a must also arise via addition to the carbon-carbon double bond of 1. Conjugate attack results in loss of identity of the geminal phenyl groups of 2a and necessitates the production of the tetradeuteroindenone 9b and the pentadeuteroindenone 9c. However, attack of phenyllithium at the carbonyl carbon would result in the exclusive formation of indenone 9b. In fact, the mass spectrum of deuterated indenone (undeuterated indenone has m/e 282, 265, and 252) exhibited peaks at m/e 287, 286, 270, 269, 257, and 256, consistent with the production of both 9b and 9c.

There are two mechanistic pathways ("x" and "y") which can account for the formation of carboxylic acids 7a and 7b. Initial conjugate addition of the organolithium reagent to 1 affords the intermediate cyclopropenolate anion 2. Ring-chain rearrangement of 2 would give the ketenyl anion 3 which upon subsequent hydrolysis would afford carboxylic acid 7 via ketene intermediate 5. Alternatively, protonation of 2 could afford a cyclopropanone intermediate 4 which could yield carboxylic acid 7 by ring opening of the cyclopropanone hydrate 6.[16-18] It should be pointed out, however, that the operation of path "y" would require selective cleavage of 6 since carboxylic acids 8a and 8b were not observed in these reactions.

Path "x" is the preferred mechanistic course for the following reasons: (1) It accounts for the selective formation of carboxylic acids 7a and 7b. (2) The formation of indenone 9a is best rationalized by cyclization of ketenyl anion 3a followed by oxidation with the formal


1
+ RLi
2
"x"
3
"y"
KH2PO4
H2O
4
5
6
7
8
(a) R = Ph
(b) R = Ph2CH
9a
9b
9c
D4
C6D5

loss of lithium hydride. (3) If the reaction mixture resulting from the addition of 1 to a solution of phenyllithium in THF at -70° is quenched with mesitoic acid,[19] an infrared spectrum taken immediately thereafter reveals a band at 2100 cm^{-1} (presumably due to ketene 5̈a [20]) which disappears with time.

Actually, the formation of 5 does not demand the intermediacy of 3 since 5 may arise from 2 directly. Furthermore the question of a possible equilibrium between 2 and 3 or perhaps the existence of a delocalized intermediate which incorporates the features of 2 and 3 must remain open. Further mechanistic studies are in progress.

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REFERENCES AND FOOTNOTES

1. Present address: Istituto di Chimica Organica dell'Universita, Padova, Italy.

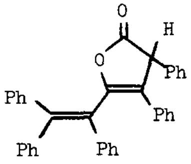
2. (a) For a communication of the reaction of t-butyllithium with di-t-butylcyclopropenone see J. Ciabattoni and E. C. Nathan, III, J. Am. Chem. Soc., 90, 4495 (1968); J. Ciabattoni and E. C. Nathan, III, full paper submitted for publication; (b) Phenylmagnesium bromide attacks the carbonyl carbon of diphenylcyclopropenone to give after appropriate work up the triphenylcyclopropenyl cation. This reaction reportedly does not work well with some aliphatic Grignard reagents. R. Breslow, T. Eicher, A. Krebs, R. A. Peterson, and J. Posner, ibid., 87, 1320 (1965); (c) R. Breslow, L. J. Altman, A. Krebs, E. Mohacsi, I. Murata, R. A. Peterson, and J. Posner, ibid., 87, 1326 (1965); (d) E. D. Bergman and I. Agranat, Israel J. Chem., 3, 197 (1965).

3. For a study of the reaction of organometallic compounds with tropone see (a) G. L. Closs, and L. E. Closs, J. Am. Chem. Soc., 83, 599 (1961); (b) T. Nozoe, T. Mukai, and T. Tezuka, Bull. Chem. Soc. Japan, 34, 619 (1961).

4. (a) Alpha-nucleophiles such as hydroxylamine and hydroperoxide anion react with diphenylcyclopropenone to give unusual products which apparently arise via initial conjugate addition. See ref. 2b and S. Marmor and M. M. Thomas, J. Org. Chem., 32, 252 (1967); (b) See also T. Eicher and A. Hansen, Tetrahedron Letters, 1169 (1967).

5. For reviews of cyclopropenone chemistry see (a) A. Krebs, Angew. Chem. Intern. Ed. Engl., 4, 10 (1965); (b) G. L. Closs in "Advances in Alicyclic Chemistry," Vol. I, H. Hart and G. J. Karabatsos, Ed., Academic Press Inc., New York, N. Y., 1966, pp. 114-121.

6. In contrast to normal addition the inverse addition of phenyllithium to 1 in THF results in the formation of a crystalline solid, mp 189-191°, to which we have tentatively assigned the enol lactone structure 10 on the basis of microanalytical and spectral data.



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7. Commercially available from Alfa Inorganics, Inc., Beverly, Mass., as a 2M solution in 70:30 benzene:ether.

8. C. R. Hauser and W. J. Chambers, J. Am. Chem. Soc., 78, 4942 (1956).

9. The yields in these organometallic reactions were inconsistent from reaction to reaction. Yields also varied with both work-up and reaction conditions and the values reported here are not necessarily optimal.

10. B. W. Rockett and C. R. Hauser, J. Org. Chem., 29, 1394 (1964).

11. An authentic sample was obtained from the Aldrich Chemical Company, Milwaukee, Wisconsin.

12. Prepared by the reaction of n-butyllithium (Foote) with diphenylmethane in THF.

13. The lower melting epimer despite repeated recrystallization was always contaminated with small amounts of the higher melting epimer.

14. D. Lednicer and C. R. Hauser, J. Am. Chem. Soc., 80, 3409 (1958).

15. Prepared by the reaction of bromobenzene-d_5 with lithium metal.

16. For a review of cyclopropanone chemistry see N. J. Turro, Accounts Chem. Res., 2, 25 (1969).

17. For a review of cyclopropanol chemistry see C. H. DePuy, ibid., 1, 33 (1968).

18. It should be pointed out that both electronic and steric factors may operate in the ring opening of cyclopropanones and cyclopropanols. See ref. 16, 17 and J. K. Crandall and W. H. Machleder, J. Am. Chem. Soc., 90, 7347 (1968).

19. Mesitoic acid was chosen as the proton source because of the poor nucleophilic properties of the hindered mesitoate anion.

20. K. Nakanishi, "Infrared Absorption Spectroscopy," Holden-Day Inc., San Francisco Calif., 1962, p. 29.