to give the observed F^{19} and H^1 line positions and intensities.[10] On this basis we assume that, with the possible exception of $J_{BF(90°)}$ in IV and V, all the coupling constants in Table I are positive in sign.[11] All six compounds had elemental analyses and infrared, ultraviolet, and nmr[12] spectra in accord with the assigned structures.

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115 (1962); D. J. Patel, M. E. H. Howden, and J. D. Roberts, *J. Am. Chem. Soc.*, **85**, 3218 (1963).

[10] This compound has been independently synthesized and its spectra were analyzed by S. Terabe and W. Funasaka with the same results (private communication). The assumption is made for this analysis that $J_{AF(cis)} > J_{BF(trans)}$.

[11] From calculated line positions and intensities, using the LAOCOON II computer program of A. A. Bothner-By, it is not possible to ascertain whether J_{BF} in IV and V is positive or negative in sign.

[12] Fluorine and proton nmr spectra were determined on A-60, DP-60, HR-60, and HA-100 spectrometers located at the University of Massachusetts and Cornell University. Compounds I, III, and VI were run as 10% (w/v) solutions in $CDCl_3$, compound II as a 10% (w/v) solution in dimethylformamide, and compounds IV and V as 10 and 20% (w/v) solutions in CD_3COCD_3 and CD_3CN. The aromatic protons in II and III were decoupled from H_B to facilitate analysis. The 100-MHz proton spectrum of IV was completely decoupled in the frequency sweep mode.

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Stable Conformations of Polyamino Acid Helices[1]

Sir:

Recently Scott and Scheraga[2] have computed energy contour diagrams for helical polyglycine and poly-L-alanine, including torsional energies, nonbonded interactions, hydrogen bonding, and electrostatic interactions. By carrying out energy minimization calculations, they found that the right-handed α-helix of poly-L-alanine was more stable than the left-handed one by a few tenths of a kilocalorie per residue; this energy difference is large enough to favor the right-handed form if the chain is more than 10–20 residues long.

We report here the results of similar calculations for several homopolymer polyamino acid helices (poly-L-valine, poly-β-methyl-L-aspartate, poly-γ-methyl-L-glutamate, and poly-L-tyrosine) of considerable interest in the field of biopolymers. In contrast to poly-L-alanine, for these helices one has to take into account the rotations about the single bonds in the side chains, *i.e.*, the energy must be minimized not only with respect to the dihedral angles of the backbone but also with respect to those of the side chains. The expressions used for the various energies are essentially the same as those used earlier for poly-L-alanine.[2]

In the case of poly-L-valine, the right-handed α-helix was found to be the most stable helical structure, being more stable than the left-handed α-helix by 0.6 kcal/residue. This prediction may, at first sight, seem surprising since calculations based only on a hard-sphere potential,[3] or on other nonbonded potentials,[4] and experimental results of Blout[5] and Bloom, *et al.*,[6] all seem to suggest that the α-helical form of poly-L-valine would not be the most stable one. However, it has been shown[3,7,8] that the α-helical backbone conformation can accommodate the L-valyl side chain if the latter is rotated about 10° away from a position of the torsional potential minimum. Indeed, we have found that the torsional energy required for such a rotation is more than compensated by the resulting decrease in energy from favorable nonbonded interactions including the side chain. In addition, we have obtained experimental proof that poly-L-valine can exist in the α-helical conformation. To circumvent the problem that poly-L-valine is insoluble in most solvents, we have prepared a block copolymer of the type $(\text{DL-Lys})_x$-(L-Val_x)-$(\text{DL-Lys})_x$ where $x \sim 40$, by the procedure reported previously.[9] This polymer is water soluble. Using ORD data as a criterion, the poly-L-valine portion appears to be α-helical in 98% aqueous methanol at room temperature. The evidence for the helical conformation is based on the location (233 and 198 mμ) and magnitude (m' = mean residue rotation = $-13{,}500 \pm 500°$ and $+57{,}000 \pm 6000°$) of the trough and peak, respectively, of the Cotton effect.

In the case of poly-β-methyl-L-aspartate, the left-handed α-helix was found to be more stable than the right-handed α-helix by 0.1 kcal/residue but, for poly-γ-methyl-L-glutamate, the right-handed α-helix was found to be more stable than the left-handed α-helix by 0.4 kcal/residue. The origin of the effect on screw sense lies in the interaction between the dipole of the ester group of the side chain and that of the amide group of the backbone (using a dielectric constant of 3 D.). In the absence of this dipole interaction, both poly-β-methyl-L-aspartate and poly-γ-methyl-L-glutamate would be right-handed α-helices. The dipole interaction destabilizes the right-handed form of the aspartate polymer, thereby favoring the left-handed form. The addition of another CH_2 group in the side chain, in the case of the glutamate polymer, leads to a different orientation and distance of the side-chain ester group with respect to the backbone; in this case, the dipole–dipole interaction favors the right-handed α-helix. These calculations provide the explanation for the well-known difference in screw sense between the aspartate and glutamate polymers.[10,11]

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[1] This work was supported by a research grant (GB-4766) from the National Science Foundation and by a research grant (AI-01473) from the National Institute of Allergy and Infectious Diseases of the National Institutes of Health, U. S. Public Health Service.

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[8] S. J. Leach, G. Némethy, and H. A. Scheraga, *Biopolymers*, **4**, 887 (1966) (Table IV).

[9] N. Lotan, A. Berger, E. Katchalski, R. T. Ingwall, and H. A. Scheraga, *ibid.*, **4**, 239 (1966).

[10] M. Goodman and F. Boardman, *J. Am. Chem. Soc.*, **85**, 2491 (1963).

[11] M. Goodman, E. E. Schmitt, and D. A. Yphantis, *ibid.*, **84**, 1288 (1962).

The right-handed α-helix of poly-L-tyrosine was found to be more stable than the left-handed α-helix by 1.7 kcal/residue. In view of complications, resulting from the presence of the tyrosyl chromophore, in the interpretation of experimental ORD data for poly-L-tyrosine,[12,13] the calculations reported here provide additional evidence that this polymer exists in the right-handed α-helical form when the tyrosyl side chains are un-ionized.

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(12) G. D. Fasman, E. Bodenheimer, and C. Lindblow, *Biochemistry*, 3, 1665 (1965).

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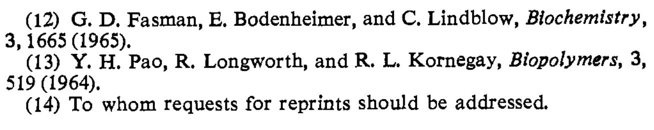
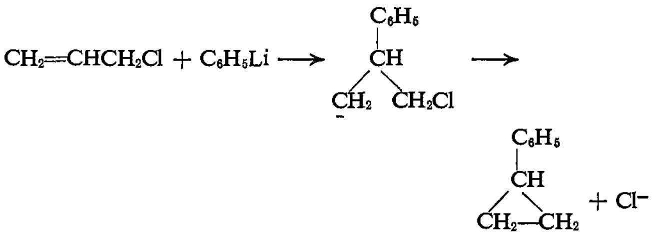
A Carbene Mechanism for the Formation of Phenylcyclopropane from Allyl Chloride and Phenyllithium

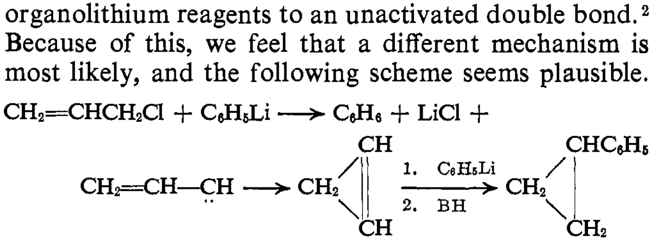
Sir:

It has recently been reported[1] that the reaction of allyl chloride with phenyllithium yielded phenylcyclopropane in addition to the expected major product, allylbenzene. Other allylic chlorides underwent similar transformations. The mechanism proposed[1] for cyclopropane formation involved addition of phenyllithium at the β-carbon atom followed by ring closure with expulsion of chloride ion.



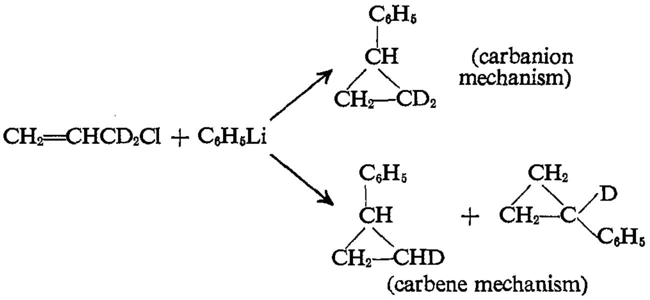


The literature reveals few examples of the addition of organolithium reagents to an unactivated double bond.[2] Because of this, we feel that a different mechanism is most likely, and the following scheme seems plausible.



Organolithium-catalyzed α elimination of an allylic halide to an alkenyl carbene[3] and subsequent cyclopropene formation is a well-established process;[5] while the addition of phenyllithium to a cyclopropene has not been observed, other nucleophiles are known to add to the double bond of a three-membered ring.[6]

As a means of differentiating between the two mechanisms, we investigated the reaction of phenyllithium with allyl-1,1-d_2 chloride. Were the carbanion mechanism operative, phenylcyclopropane-2,2-d_2 would be the product; if, on the other hand, the carbene mechanism were correct, the product would consist of an approximately equal mixture of phenylcyclopropane-2-d_1 and phenylcyclopropane-1-d_1.



Acrylyl chloride was reduced with lithium aluminum deuteride,[7] yielding allyl-1,1-d_2 alcohol[8] which was converted without rearrangement into allyl-1,1-d_2 chloride[9] by the action of thionyl chloride and tri-*n*-butylamine.[10] The reaction of allyl-1,1-d_2 chloride with phenyllithium in refluxing ether for 5 hr yielded allylbenzene and phenylcyclopropane in 55–62 and 0.9–1.1%, respectively, of the theoretical yields based upon allyl chloride.[11]

The following observations are consistent with the α-elimination mechanism and contrary to predictions based upon the carbanion mechanism.

(1) Phenylcyclopropane from allyl-1,1-d_2 chloride was approximately 90% monodeuterated, 7% dideuterated, and 3% undeuterated.[12] The integrated areas

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(1) (a) S. Wawzonek, B. Studnicka, H. J. Bluhm, and R. E. Kallio, *J. Am. Chem. Soc.*, 87, 2069 (1965); (b) S. Wawzonek, H. J. Bluhm, B. Studnicka, R. E. Kallio, and E. J. McKenna, *J. Org. Chem.*, 30, 3028 (1965).

(2) (a) *Cf.* J. E. Mulvaney and Z. G. Garlund, *ibid.*, 30, 917 (1965). (b) An intramolecular addition of a Grignard reagent to an isolated double bond has recently been reported: H. G. Richey, Jr., and T. C. Rees, *Tetrahedron Letters*, 4297 (1966).

(3) We use the term carbene for simplicity, being fully aware of current thinking that divalent carbon species are not intermediates in α eliminations.[4]

(4) (a) G. L. Closs and J. J. Coyle, *J. Am. Chem. Soc.*, 87, 4270 (1965); (b) G. L. Closs and R. A. Moss, *ibid.*, 86, 4042 (1964); (c) M. J. Goldstein and W. R. Dolbier, Jr., *ibid.*, 87, 2293 (1965).

(5) G. L. Closs and L. E. Closs, *ibid.*, 83, 2015 (1961); 85, 99 (1963).

(6) R. Breslow and P. Dowd, *ibid.*, 85, 2729 (1963).

(7) R. D. Schuetz and F. W. Millard, *J. Org. Chem.*, 24, 297 (1959).

(8) The sample contained 1.95 deuterium atoms at C_1 as established by nmr analysis.

(9) The sample contained 2.00 deuterium atoms at C_1 as established by nmr analysis and greater than 1.90 deuterium atoms by mass spectral analysis.

(10) S. H. Sharmon, F. F. Caserio, J. C. Leak, and W. G. Young, *J. Am. Chem. Soc.*, 80, 5965 (1958).

(11) The yields with undeuterated allyl chloride under identical conditions were 29–37 and 8–10%, respectively; total hydrocarbon yields from deuterated material of as high as 85% have been obtained using excess phenyllithium, but this leads to the extensive isomerization of allylbenzene to β-methylstyrene which interferes with our method of isolating phenylcyclopropane.

(12) We are currently reinvestigating the products formed from allyl-1,1-d_2 chloride in an attempt to determine the deuterium content of phenylcyclopropane more accurately. We suspect that the small amount of dideuterated phenylcyclopropane is due not to the carbanion mechanism but rather to abstraction of a deuteron from allylbenzene-d_2.[13]

(13) D. E. Applequist and M. A. Lintner (*J. Org. Chem.*, 31, 3062 (1966)) have shown that quenching of the allyl chloride–phenyllithium reaction mixture with deuterium oxide does not lead to incorporation of the isotope into phenylcyclopropane. We have observed the identical result but, since all of our data point to the α-elimination mechanism, we believe that 2-phenylcyclopropyllithium