strated.[2] It is electron exchange between the cycloöctatetraenyl dianion and the anion-radical, the proton resonance of which occurs nine megacyles outside the n.m.r. range to either side,[4] which readily accounts for the observed broad resonance line of the dianion just before two moles of potassium have dissolved. These data—the observed half-width of the broad line in spectrum V, the concentration ratio at this stage of dianion to cyclooctatetraene (about 100:3), and the known equilibrium constant for the disproportionation of the anion-radical[3] allow calculation of the second order rate constant for exchange between the dianion and the anion-radical: *ca.* 1×10^9 liters mole^{-1} sec.$^{-1}$.[5]

That the n.m.r. spectrum of cycloöctatetraene itself is throughout sharp implies that electron exchange between the anion-radical and the hydrocarbon is more than one hundred thousand times slower than between the anion-radical and the dianion, the exact opposite of the behavior observed in polynuclear aromatic systems.[6] The superposition of a sharp line due to cycloöctatetraene on the broad dianion peak, with little chemical shift between them implies that exchange between these species also is relatively slow. The lack of exchange reactivity of the hydrocarbon, cycloöctatetraene, by comparison with its dianion finds most ready explanation if *the dianion and the anion-radical are both planar*, the electron exchange being almost unactivated only in the absence of appreciable geometrical change.

The n.m.r. spectra in the lithium cycloöctatetraene system are equally revealing. The decrease in intensity of the continually sharp cyclooctatetraene resonance is accompanied by the rise of a line which narrows to field-determined width and expected intensity when two moles of lithium dissolve. At half reaction the lines are separated by 2 cycles. These observations and those of fully resolved *esr.* spectra of intensity comparable to those in the potassium series imply a considerably slower electron exchange rate (*ca.* ten thousandfold) in the lithium series. Although the cations were, for convenience, neglected above, their role is clearly significant.[7]

Acknowledgment.—The invaluable assistance of Mr. John S. Martin, who skillfully and patiently determined the n.m.r. spectra is gratefully acknowledged.

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(4) Nine megacycles is in frequency units the previously reported[2] proton hyperfine interaction observed in the esr. spectrum of the anion-radical.

(5) The relationship between the half half-width, $\Delta\nu$, of the proton n.m.r. line due to exchange of the dianion ($R^{=}$) with the anion radical ($R^{\dot{-}}$) is

$$2\pi\Delta\nu = \frac{k(R^{\dot{-}})(\delta\omega)^2}{(\delta\omega)^2 + k^2(R^{=})^2}$$

where k is the second order rate constant for exchange and $\delta\omega$ is the *esr.* proton hyperfine splitting in angular frequency. If $k(R^{=}) >> \delta\omega$ the *esr.* spectrum will be broad and in the n.m.r.

$$2\pi\Delta\nu = \frac{(R^{\dot{-}})(\delta\omega)^2}{k(R^{=})^2}$$

That the width of the broad n.m.r. line is independent of temperature, while the enthalpy of disproportionation of the anion-radical is negative[3] seems in accord only with the choice of the exchange sharpening term. The independent deduction that the hyperfine splitting of the *esr.* spectrum would only be resolvable when small amounts (<10%) of potassium were dissolved is, in fact, confirmed.

(6) R. L. Ward and S. I. Weissman, THIS JOURNAL, **79,** 2086 (1957); A. Carrington, F. Dravnieks and M. C. R. Symons, *J. Chem. Soc.*, 947 (1959).

(7) The relationship of the cations to the cycloöctatetraenyl anions is now still ill-defined, although strong ion pairing, such as probably occurs in the better known polycyclic aromatic alkali metal adducts, undoubtedly is involved.

(8) P. Balk, G. J. Hoijtink and J. W. H. Schreurs, *Rec. trav. chim.*, **76**, 813 (1957); G. J. Hoijtink, E. de Boer, P. H. van der Meij and W. P. Weijland, *Rec. trav. chim.*, **75**, 487 (1956).

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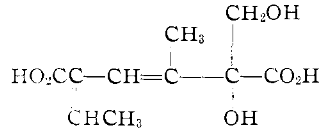
RECEIVED JUNE 6, 1960

STEREOCHEMISTRY OF NECIC ACIDS

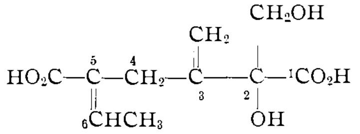
Sir:

In a previous paper[1] from this Laboratory, structure I was proposed for riddellic acid, the alkaline hydrolysis product of riddelliine.



$$\mathrm{HO_2C\underset{\displaystyle CHCH_3}{C}{-}CH{=}\overset{\displaystyle CH_3}{\overset{|}{C}}{-}{-}\overset{\displaystyle CH_2OH}{\underset{\displaystyle OH}{C}}{-}CO_2H}$$

I



$$\mathrm{HO_2C{-}\underset{\displaystyle \|\atop {}_6CHCH_3}{\overset{5}{C}}{-}\overset{4}{C}H_2{-}\underset{3}{\overset{\displaystyle CH_2 \atop \|}{C}}{-}{-}\underset{\displaystyle {}^{2}|\atop OH}{\overset{\displaystyle CH_2OH\atop |}{C}}{-}{}^{1}CO_2H}$$

II

In view of the results recently reported on the structure of isoseneciphyllic acid,[2] the structure of riddellic acid has been reinvestigated[3] and evidence has now been obtained favoring structure II.

The establishment of structure II for riddellic acid and a similar structure for seneciphyllic acid[2] has reduced the unknown stereochemical factors in the structures of the majority of C_{10} necic acids to that of the *cis-trans* isomerism of the 5,6 double bond. The problem of the absolute configuration of the C_2 still has been unstudied.

The usefulness of n.m.r. spectroscopy in establishing the stereochemistry of olefins and olefinic acids has been demonstrated recently in several cases.[4,5,6,7] We have determined the n.m.r. spectra of a number of *cis* and *trans* trisubstituted olefinic acids and their esters and have gathered significant data pertaining to the geometry of these acids. The results are given in the table.

An examination of the table reveals: (1) The relative positions of the resonance lines of the olefinic proton are characteristic of its stereochemistry; (2) The shielding value of the single proton in the *trans* compound is always lower than that of the corresponding *cis* isomer. (3) An insignificant

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(1) R. Adams and B. L. Van Duuren, THIS JOURNAL, **75**, 4638 (1953).

(2) T. Masamune, *Chem. and Ind.*, 21 (1959).

(3) The details of these investigations will be presented shortly in a forthcoming publication.

(4) L. M. Jackman and R. H. Wiley, *Proc. Chem. Soc.*, 196 (1958).

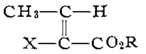
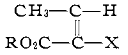
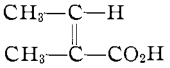
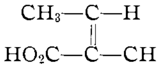
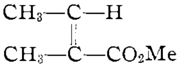
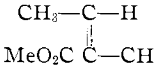
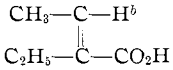
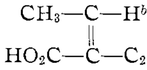
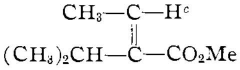
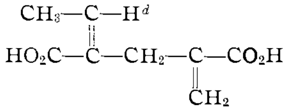
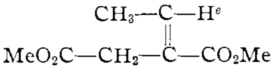
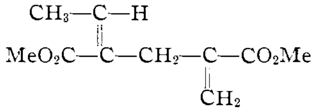
(5) R. R. Fraser, *Can. J. Chem.*, **38**, 549 (1960).

(6) J. W. K. Burrell, L. M. Jackman and B. C. L. Weedon, *Proc. Chem. Soc.*, 263 (1959).

(7) S. Fujiwara, H. Shimizu, Y. Araba and S. Akahori, *Bull. Chem. Soc. Japan*, **33**, 428 (1960).

TABLE I

τ VALUES OF OLEFINIC PROTON IN *trans* AND *cis* (WITH RESPECT TO $-CH_3$ AND $-CO_2R$) TRISUBSTITUTED OLEFINIC ACIDS AND ESTERS[a]

 $\begin{array}{c} CH_3{-}C{-}H \\ \| \\ X{-}C{-}CO_2R \end{array}$	*trans*	 $\begin{array}{c} CH_3{-}C{-}H \\ \| \\ RO_2C{-}C{-}X \end{array}$	*cis*
 $\begin{array}{l} CH_3{-}C{-}H \\ \quad \| \\ CH_3{-}C{-}CO_2H \end{array}$	3.03	 $\begin{array}{l} CH_3{-}C{-}H \\ \quad \| \\ HO_2C{-}C{-}CH_3 \end{array}$	3.82
 $\begin{array}{l} CH_3{-}C{-}H \\ \quad \| \\ CH_3{-}C{-}CO_2Me \end{array}$	3.28	 $\begin{array}{l} CH_3{-}C{-}H \\ \quad \| \\ MeO_2C\ C{-}CH_3 \end{array}$	4.03
 $\begin{array}{l} CH_3{-}C{-}H^b \\ \quad \| \\ C_2H_5{-}C{-}CO_2H \end{array}$	3.00	 $\begin{array}{l} CH_3{-}C{-}H^b \\ \quad \| \\ HO_2C{-}C{-}C_2H_5 \end{array}$	3.82
 $\begin{array}{r} CH_3{-}C{-}H^c \\ \| \quad \\ (CH_3)_2CH{-}C{-}CO_2Me \end{array}$	3.3	 $\begin{array}{l} CH_3{-}C{-}H^d \\ \quad \| \\ HO_2C{-}C{-}CH_2{-}C{-}CO_2H \\ \qquad\qquad\qquad \| \\ \qquad\qquad\quad CH_2 \end{array}$	3.70
 $\begin{array}{r} CH_3{-}C{-}H^e \\ \| \quad \\ MeO_2C{-}CH_2{-}C{-}CO_2Me \end{array}$	3.2	 $\begin{array}{l} CH_3{-}C{-}H \\ \quad \| \\ MeO_2C{-}C{-}CH_2{-}C{-}CO_2Me \\ \qquad\qquad\qquad\quad \| \\ \qquad\qquad\qquad CH_2 \end{array}$	3.95
Dimethyl integerrinecate	3.24	Dimethyl senecate	3.99
		Dimethyl riddellate	3.96
		Dimethyl seneciphyllate	3.90

[a] All spectra were determined on a Varian high resolution spectrometer at 60 Mc. per second. We are thankful to Mr. T. Van Auken for providing the spectra of tiglic and angelic acids and their esters (run in CCl_4). All other spectra were obtained in $CDCl_3$ using tetramethylsilane as an internal standard. Values are expressed in parts per million on the "τ scale" as defined by Tiers (*J. Phys. Chem.*, **62**, 1151 (1958)). The peaks due to the single proton appeared in all case as quartets and the values are reported for the center of each quartet. All the compounds studied except α-ethylisocrotonic acid were isomerically pure. The sample of α-ethylisocrotonic acid available was a mixture of *cis* and *trans* compounds and consequently had quartets at 3.00 and 3.82 corresponding to *cis* and *trans* protons. We are grateful to Professor T. A. Geissman for a gift of senecic acid and to the A. P. Sloan Foundation for a grant which made this investigation possible. [b] E. Blaise and P. Bagard, *Ann. Chim.*, 11, 111 (1907). [c] R. Adams and B. L. Van Duuren, THIS JOURNAL, **74**, 5349 (1952). [d] Ref. 1. [e] M. C. Kloetzel, *ibid.*, **70**, 3571 (1948).

shift occurs in the τ value of the olefinic proton on changing the substituent X from $-CH_3$ to $-C_2H_5$ to $-CH(CH_3)_2$, etc. (4) The close agreement bebetween the values of the olefinic proton in methyl tiglate, methyl isopropylcrotonate, dimethyl ethylidenesuccinate and dimethyl integerrinecate indicates that in all these cases the proton is oriented *cis* to the carbomethoxyl groups. Similarly, the values for methyl angelate, dimethyl senecate, dimethyl α-methylene-α′-ethylideneglutarate (obtained from riddellic acid), dimethyl riddellate, and dimethyl seneciphyllate all have the same arrangement of groups about the double bond. (5) A small shift of the τ value of the olefin proton toward higher field side is observed in the ester of an acid.[8]

The sensitivity of this correlation of the *cis* and *trans* isomers is apparent by comparing the difference of the values of the ethylidenic protons in the *cis–trans* pair dimethyl senecate and dimethyl integerrinecate with the differences of the values of the pairs methyl angelate and methyl tiglate, and α-ethylcrotonic acid and α-ethylisocrotonic acid. Thus orientation of groups about the olefin linkage in the necic acids, assigned on the basis of ultraviolet spectra and melting points, is confirmed.

The shielding values of the methyl protons also could be used[4] for determining the stereochemistry of the double bond, but the single proton values are to be preferred due to their larger sensitivity to environmental changes. Between the *cis* and *trans* compounds the shift in the methyl proton values is about 0.2 p.p.m. whereas the shift in the olefinic proton values is about 0.8 p.p.m. There is some evidence also that n.m.r. spectroscopy provides a valuable tool for determining the compositions of mixtures of *cis* and *trans* trisubstituted olefinic acids.

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RECEIVED JUNE 8, 1960

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[8] N. J. Leonard in "The Alkaloids," edited by R. H. F. Manske, Vol. VI, Chapter 3, Academic Press, New York, N. Y., 1960.

THE DEPENDENCE OF THE CONFORMATIONS OF SYNTHETIC POLYPEPTIDES ON AMINO ACID COMPOSITION[1,2]

Sir:

Several years ago the α helix[3] was demonstrated by X-ray diffraction in a few synthetic polypeptides[4,5,6] and recently has been shown to be a basic

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[1] This is Polypeptides. XXX. For the preceding paper in this series see E. Katchalski, G. D. Fasman, E. Simons, E. R. Blout, F. R. N. Gurd and W. L. Koltun, *Arch. Biochem. Biophys.*, **88**, 361 (1960). Alternate address for E. R. Blout, Chemical Research Laboratory, Polaroid Corporation, Cambridge 39, Massachusetts.

[2] This work was supported in part by U. S. Public Health Service Grant A2558 and by the Department of the Army, Office of the Surgeon General.

[3] L. Pauling, R. B. Corey and H. R. Branson, *Proc. Natl. Acad. Sci., U. S.*, **37**, 205 (1951), et seq.

[4] C. H. Bamford, W. E. Hanby and F. Happey, *Proc. Roy. Soc. (London)*, **206A**, 30 (1951); C. H. Bamford, L. Brown, A. Elliott, W. E. Hanby and I. F. Trotter, *ibid.*, **141B**, 49 (1953); C. H. Bamford, L. Brown, A. Elliott, W. E. Hanby and I. F. Trotter, *Nature*, **173**, 27 (1954).

[5] M. F. Perutz, *ibid.*, **167**, 1053 (1951).

[6] H. L. Yakel, *Acta Cryst.*, **6**, 724 (1953).