Similar experiments with $Fe(CO)_5$ have yielded a band at 1834 cm.$^{-1}$ which we believe to be due to the formation of a tetracoördinated iron carbonyl. Work on this complex and the lower complexes of Cr and Mo is continuing.

DEPARTMENT OF CHEMISTRY
FLORIDA STATE UNIVERSITY
TALLAHASSEE, FLORIDA
INGO W. STOLZ
GERARD R. DOBSON
RAYMOND K. SHELINE

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A RACEMIC COMPOUND OF α-HELICAL POLYPEPTIDE

Sir:

The existence of racemic mixtures, racemic solid solutions and racemic compounds of low molecular weight organic compounds in the solid state has been confirmed by various physical methods.[1] On the other hand, data pertaining to racemic interactions in liquid solutions have been inconclusive.[2-5] We wish to present evidence that macromolecular compounds, the helical homopolypeptides of γ-methyl-D- and L-glutamate, form a definite racemic compound in solution as well as in the solid state.

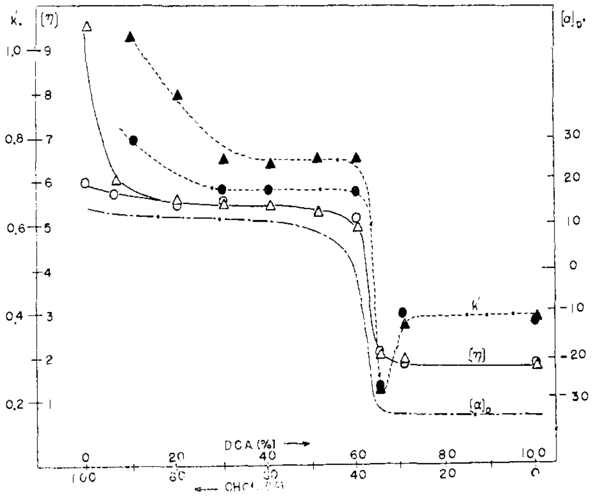

Fig. 1.—Dependence of Huggins' constant and intrinsic viscosity for L-PMG (DP = 1,700) and a mixture of L- and D-PMG (DP = 1,700) on solvent composition: ———, $[\eta]$; --------, k; –O– and –●–, L-PMG; –△– and –▲–, 1:1 mixture of L- and D-PMG; semi-solid line represents $[\alpha]_D$ curve for L-isomer.

The behavior of a chloroform or a chloroform–dioxane solution of either α-helical poly-γ-methyl D- or L-glutamate (D- or L-PMG) was found to be remarkably different from that of a 1:1 mixture of the two enantiomorphs in the same solution. When chloroform–dioxane (2:1 by volume) solutions of D- and L-PMG (each 8.5 g./100 ml., DP = 2,900) were mixed at 37°, the resulting mixture changed into a rigid gel accompanied by a slight phase separation. The phenomenon was much more straightforward when a dimethylformamide (DMF) solution, in which the polypeptide chain exists also as an α-helix, was employed. Blending the enantiomorphic PMG solutions in DMF (1 g./100 ml., DP = 1,700) at 100° resulted in immediate precipitation of a white polymeric material lacking optical activity. Moreover, blending of DMF solutions of D- and L-PMG (DP = 1,700) in different proportions at 100° gave similar precipitates, the weights and optical rotations of which were compared with those of the PMG which remained in solution (Table I). Irrespective of the proportions in which the two enantiomorphic polypeptides were mixed, the weight of the precipitate was twice that of the lesser component.

TABLE I

COMPARISON OF WEIGHTS AND SPECIFIC OPTICAL ROTATIONS FOR THE PRECIPITATE AND PMG REMAINING IN LIQUID PHASE UPON BLENDING DMF SOLUTIONS OF D- AND L-PMG IN DIFFERENT PROPORTIONS

Initial ratio	D-PMG	1	3	1
	L-PMG	1	1	5
Initial wt., g.	D-PMG	1.000	1.667	0.201
	L-PMG	1.000	0.566	1.001
Precipitate[a]	Wt., g.	1.980	1.002	0.405
	$[\alpha]^{30}D$	0.00	−0.31	0.00
PMG left in liq.[b]	Wt., g.	0	0.947	0.693
	$[\alpha]^{30}D$	..	−7.84	+9.32

[a] Optical rotations were measured in dichloroacetic acid-chloroform (1:4 by volume,[6] c = 1.6). [b] The remaining polymer was completely precipitated from the solution by addition of a large amount of water and dried, then measurements were carried out in the same solvent system.

The precipitate showed in the solid state and in chloroform solution the same infrared absorption bands (amide I at 1650 cm.$^{-1}$ and amide II at 1545 cm.$^{-1}$) characteristic of α-helix as was observed on either enantiomorph. These results, together with the fact that the polypeptide modification obtained is less soluble than either enantiomorph, indicate that the precipitated material is a 1:1 mixture of *α-helical* D- and L-PMG, which reasonably may be called a "racemic compound" as in the case of monomeric compounds.

In order to ascertain whether this modification remains a racemic compound in solution or dissociates to the original components, viscosity measurements and estimates of the Huggins constant k' in the expression: $\eta_{sp}/c = [\eta] + k' [\eta]^2c$, where η_{sp}, c and $[\eta]$ are specific viscosity, concentration and intrinsic viscosity, respectively, were made at various compositions of the coil-producing solvent dichloroacetic acid (DCA) and the helix-forming chloroform (Fig. 1). The results are: (1) $[\eta]$ and k' values for both optically active and racemic PMG are related to molecular configuration as measured by optical rotation of the active form. Abrupt change in all of these properties takes place at 60 volume % DCA, where the helix–coil transition of PMG occurs. (2) Both active and racemic PMG show much higher $[\eta]$ and k' values in the helical region (up to 60 % DCA) than those in the coil region (above 60 % DCA).[7] This would be due to associa-

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(1) H. Gilman, "Organic Chemistry," Vol. I, 2nd ed., John Wiley and Sons, New York, N. Y., 1948, p. 248.

(2) R. Anschütz, *Liebigs Ann. Chem.*, **247**, 111 (1888).

(3) P. Frankland and R. H. Piccard, *J. Chem. Soc.*, **69**, 123 (1896).

(4) A. Cotton, *Ann. Chim. (Paris)*, [7] **8**, 347 (1896).

(5) A. Byk, *Ber.*, **37**, 4696 (1904).

(6) In this solvent the optically active PMG is an α-helix; see Fig. 1.

(7) G. E. Perlmann and E. Katchalski, *J. Am. Chem. Soc.*, **84**, 452 (1962).

tion of helical molecules.[8] (3) The modification has greater $[\eta]$ values near 100% chloroform and greater k' values over the whole helical region than the enantiomorph, while in the coil region the curves are quite identical. Furthermore, by applying the molecular weight–intrinsic viscosity (in chloroform) relationship[9] for the enantiomorph it was found that a racemic modification shows the $[\eta]_{\mathrm{CHCl_3}}$ value corresponding to a molecular weight approximately twice that of the enantiomorph of which it is composed. These results suggest that in solution in helix-forming media the enantiomorphic forms are in some way combined with each other and that the association of D-chain-L-chain is of higher order than that of L(or D)-chain-L(or D)-chain, provided k' gives a measure of association.

From the data presented we believe that the present polypeptide modification exists in solid and in solution not as a merely stoichiometric mixture of the two enantiomorphs but as a racemic compound. At present we have no evidence indicating that the formation of this macromolecular racemic compound is due to a side chain–side chain interaction between D- and L-polypeptide chains.[10]

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[8] P. Doty, J. H. Bradbury and A. Holtzer, *J. Am. Chem. Soc.*, **78**, 947 (1956).

[9] This was prepared, using several L-PMG samples, by correlating their intrinsic viscosities obtained in chloroform with the molecular weights estimated from light scattering data in DCA.

[10] M. Tsuboi, A. Wada and N. Nagashima, *J. Mol. Biol.*, **3**, 705 (1961).

CENTRAL RESEARCH LABORATORY
AJINOMOTO CO., INC.
KAWASAKI, JAPAN
TŌICHI YOSHIDA
SETSUJI SAKURAI
TŌRU OKUDA
YASUO TAKAGI

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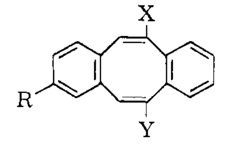
OPTICAL RESOLUTION OF A 1,2,5,6-DIBENZCYCLOÖCTATETRAENE DERIVATIVE

Sir:

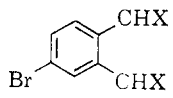
Cycloöctatetraene exists predominantly in the D_{2d} tub conformation.[1] The problem of electron delocalization in this and in the planar forms (D_{4h} or D_{8h}) continues to attract attention, as does the related question of the strain energy introduced in the conversion of the tub into the planar forms.[2]

Racemization studies on dissymmetric cycloöctatetraene derivatives could lead to an experimental estimate of the energy difference between tub and planar (transition state) conformations and would therefore be of considerable interest. Nevertheless, no optically active compound in this class has heretofore been reported, even though it was recognized by Cope, *et al.*,[3] and by Pechet[4] that nonplanarity could in principle be demonstrated by the optical resolution of mono-substituted cycloöctatetraenes[3] and of dibenzcycloöctatetraenes of formula Ia.[4] We now wish to report the first resolution of a substituted cycloöctatetraene derivative, the dibenzcycloöctetraene Ib.

Irradiative bromination of 4-bromo-*o*-xylene gave IIa, m.p. 113–115°, which was hydrolyzed (fuming sulfuric acid) to IIb, m.p. 98–100°. Condensation with *o*-phenylenediacetonitrile to Ic, m.p. 242–244°, followed by hydrolysis (phosphoric-acetic acid mixture), gave Ib, m.p. 290–292° (dec.). All compounds gave satisfactory elemental analyses for carbon, hydrogen, bromine and (in the case of Ic) nitrogen. Resolution *via* the brucine salt gave optically active enantiomers of Ib, $[\alpha]^{21}\mathrm{D} + 71.2°$ and $[\alpha]^{26}\mathrm{D} - 61.6°$ (c 0.9, ethanol).



Ia, $X \neq Y, R = H$
b, $X = Y = \mathrm{COOH}, R = \mathrm{Br}$
c, $X = Y = \mathrm{CN}, R = \mathrm{Br}$
d, $X = Y = \mathrm{H}, R \neq \mathrm{H}$



IIa, $X = \mathrm{Br_2}$
b, $X = \mathrm{O}$

Solutions of the compound which were allowed to stand for at least eight weeks at room temperature exhibited no loss of optical activity. However, at elevated temperatures the interconversion of enantiomers (Fig. 1) becomes an important process.

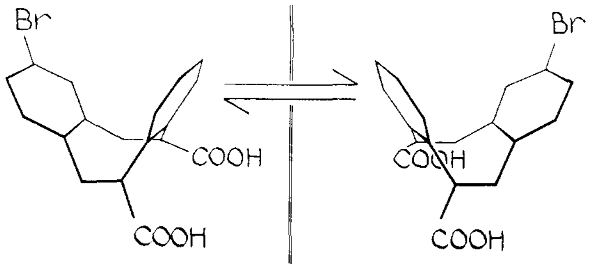


Fig. 1.

In preliminary experiments we have found that Ib in diethylene glycol diethyl ether racemizes at 120, 130 and 140° with a half-life of approximately 140, 62 and 25 minutes, respectively. The estimated E_{act} is 27 kcal./mole. The calculated pre-exponential term (10^{11} sec.$^{-1}$) falls well within the range of values (10^{10} to 10^{13} sec.$^{-1}$) most frequently reported for the common optically labile atropisomers, such as the biphenyls.[5]

The demonstrated potential barrier is recognized to be an *upper limit* for cycloöctatetraene. The presence of the two benzene rings undoubtedly minimizes any effect of π-electron delocalization on the stabilization of the planar transition state, relative to the nonplanar ground state: such an effect could possibly be an important factor in the conversion of cycloöctatetraene to the planar forms.[2] In addition, inspection of models reveals that non-

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[1] W. B. Person, G. C. Pimentel and K. S. Pitzer, *J. Am. Chem. Soc.*, **74**, 3437 (1952); O. Bastiansen, L. Hedberg and K. Hedberg, *J. Chem. Phys.*, **27**, 1311 (1957).

[2] A. Streitwieser, Jr., "Molecular Orbital Theory for Organic Chemists," John Wiley and Sons, Inc., New York, N. Y., 1961, Chapter 10.7; G. Ahlers and J. F. Hornig, *J. Phys. Chem.*, **65**, 2102 (1961); C. A. Coulson, *Tetrahedron*, **12**, 193 (1961); N. L. Allinger, *J. Org. Chem.*, **27**, 443 (1962); F. A. L. Anet, *J. Am. Chem. Soc.*, **84**, 671 (1962); T. J. Katz, W. H. Reinmuth and D. E. Smith, *ibid.*, **84**, 802 (1962); O. Bastiansen and M. Traetteberg, *Tetrahedron*, **17**, 147 (1962); C. A. Coulson and W. T. Dixon, *ibid.*, **17**, 215 (1962).

[3] A. C. Cope and M. R. Kinter, *J. Am. Chem. Soc.*, **73**, 3424 (1951); A. C. Cope, M. Burg and S. W. Fenton, *ibid.*, **74**, 173 (1952).

[4] M. M. Pechet, Ph.D. Dissertation, Harvard University, 1944; *cf.* also L. F. Fieser and M. M. Pechet, *J. Am. Chem. Soc.*, **68**, 2577 (1946).

[5] D. M. Hall and M. M. Harris, *J. Chem. Soc.*, 490 (1960).