concerning a possible role for Q_{10} in oxidative phosphorylation mechanisms; also, concerning analyses for vitamin E, since the chromanol II is a methoxy analog of vitamin E. However, the natural occurrence of the chromanol II has not yet been established.

CONTRIBUTION FROM THE
MERCK SHARP & DOHME RESEARCH LABORATORIES
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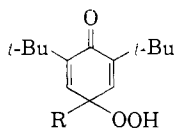
RECEIVED JULY 11, 1960

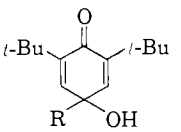
OXIDATION OF HINDERED PHENOLS TO SEMIQUINONES

Sir:

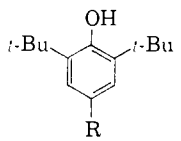
The reactions between oxygen and hindered phenols in alkaline solution have been reported in several recent papers.[1,2,3,4] The major products at low temperatures are peroxides of structure I which in alkaline solution can decompose[1,2] to II or III or rearrange to IV. Free radicals whose



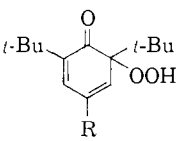
I



II



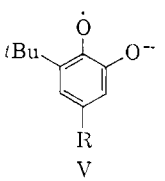
III



IV

structure has not been explained heretofore have been observed[5,6] in this system by electron spin resonance (e.s.r.) spectroscopy.

We wish to report an unusual new reaction, isobutene elimination leading to the formation of pyrocatechol semiquinones V which are responsible for the observed e.s.r. spectra (Table I).



V

The isobutene evolved has been identified by gas-liquid chromatography and mass spectrometry. Two of the suspected pyrocatechols, 3-*tert*-butyl-5-methylpyrocatechol and 3,5-di-*tert*-butylpyrocatechol, have been prepared. The e.s.r. spectra of the semiquinones of these two compounds are identical with the spectra observed on oxidation 2,6-di-*tert*-butyl-4-methylphenol and 2,4,6-tri-*tert*-butylphenol, respectively.

(1) M. S. Kharasch and B. S. Joshi, *J. Org. Chem.*, **22**, 1439 (1957).
(2) H. R. Gersmann and A. F. Bickel, *J. Chem. Soc.*, 2711 (1959).
(3) G. G. Yohe, et al., *J. Org. Chem.*, **24**, 1251 (1959).
(4) A. Fairbourn and E. A. C. Lucken, *Proc. Chem. Soc.*, 67 (1950).
(5) M. Adams, M. S. Blois, and R. H. Sands, *J. Chem. Phys.*, **28**, 774 (1958).
(6) J. K. Becconsall, S. Clough, and Gerald Scott, *Proc. Chem. Soc.*, 308 (1959).

TABLE I

PROPERTIES OF ELECTRON SPIN RESONANCE SPECTRA OF SEMIQUINONES OBTAINED BY OXIDATION OF 2,6-DI-TERT-BUTYL-4-R PHENOL

R	Approx. int. ratios of hyperfine lines	Coupling constants, gauss a_1	a_2
Methyl	1:1:3:3:3:3:1:1	5.2	2.5
Benzyl[a]	1:1:2:2:1:1	4.1	2.5
Isopropyl[a]	1:2:1	2.4	2.4
tert-Butyl	1:1	..	2.5

[a] Provided by the courtesy of Dr. F. C. Davis and Dr. G. C. Coppinger of Shell Development Company.

If I (R = CH_3) is allowed to decompose in alkaline solution, the characteristic e.s.r. spectrum of the corresponding semiquinone appears in about four hours. If an equimolar solution of I and III (R = CH_3) or an equimolar solution of cumene hydroperoxide and II is made alkaline, a strong e.s.r. spectrum appears immediately. Gersmann and Bickel[2] have suggested that an orthoquinone formed by the decomposition of IV may be responsible for the autocatalytic behavior of the main oxidation reaction. The present work indicates that orthoquinones almost certainly are produced. The mechanism of the olefin elimination reaction giving rise to the orthosemiquinones and orthoquinones is obscure. It is probably significant that the product is an orthosemiquinone rather than a parasemiquinone even if R = *t*-butyl.

Acknowledgment.—It is a pleasure to acknowledge helpful discussions with staff members of this laboratory and particularly with Dr. S. I. Weissman of Washington University and Dr. G. M. Coppinger of Shell Development Company.

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RECEIVED MAY 31, 1960

OPTICALLY ACTIVE VINYL POLYMERS. II. THE OPTICAL ACTIVITY OF ISOTACTIC AND BLOCK POLYMERS OF OPTICALLY ACTIVE α-OLEFINS IN DILUTE HYDROCARBON SOLUTION

Sir:

Although the existence of spiralized conformations of the macromolecules of many vinyl polymers in the solid state has been recognized since 1954,[1] no experimental evidence for the existence of such types of conformations in the liquid phase has been reported.

The data given here seem to support the hypothesis that, in the case of poly-α-olefins, helical conformations can exist above the melting point and in dilute solution.[2]

As we have reported recently,[3] the crystalline isotactic and block polymers of (+)(S)-3-methyl-1-

(1) G. Natta and co-workers, *Nuovo Cimento*, [X], Suppl. **15**, 1–158 (1960).

(2) G. Natta, *et al.* (private communication) have obtained some evidence for the existence of helical conformations of poly-α-olefins in solution from infrared spectra. Similar evidence has been obtained by H. Tadokoro, S. Nozakura, T. Kitazawa, Y. Yasuhura and S. Murahashi, (*Bull. Chem. Soc. Japan*, **31**, 313–315 (1958)).

(3) P. Pino, G. P. Lorenzi and L. Lardicci, abstracts of papers of Symposium for Macromolecular Chemistry, Moskow, 14–18, June, 1960. Communication to the Italian Chemical Society Meeting held in Florence on April 2nd, 1960, *Chimica e Industria*, **42**, in press (1960).

TABLE I

MELTING POINT, INTRINSIC VISCOSITY AND SPECIFIC ROTATION OF DIFFERENT FRACTIONS OF POLY-(S)-3-METHYL-1-PENTENE

Fraction	Solvent used for the extraction[a]	%[b]	Melting temp., °C.[c]	$[\eta]$ 100 cm.³/g.	$[\alpha]^{20}D$ °	c	Solv.
1	Acetone	6.3	...	[d]	+35.5 ± 0.5	1.928	Bz
2[e]	Diethyl ether	2.6	65–75	0.08 ± 0.01	+124 ± 2	0.702	Bz
3	Isoöctane	0.9	135–140	0.09 ± 0.01	+145 ± 2	0.080	Bz
4	Benzene	0.4	175–180	0.09 ± 0.01	+190 ± 10	0.018	Bz
5	Decalin	2.7	228–232	0.8 ± 0.1	+194 ± 10	0.023	Dec.
6[e]	...	87.1[f]	271–273[g]	...	...	...	...

[a] At the solvent boiling point. [b] Based on the crude polymer. [c] Determined using a Kofler m.p. apparatus. [d] Mol. wt. determined by cryoscopy in benzene, 1200. [e] The fraction shows crystallinity at the X-ray examination. [f] Residue. [g] Determined by the capillary method.

TABLE II

ROTATIONS OF PARTIALLY CRYSTALLINE POLY-(S)-5-METHYL-1-HEPTENE IN THE SOLID AND LIQUID STATE AND IN DECALIN SOLUTION AT DIFFERENT TEMPERATURES

	αD	l, dm.	t, °C.	$[\alpha]D$	$\Delta\alpha D(l = 1)/\Delta t$	$\Delta[\alpha]D/\Delta t$	Temp. interval, °C.
Solid, partially crystalline polymer[a]	+1.02	0.02	19.0	+59.6	−0.04	−0.01 *ca.*	19.0–44.5
Melted polymer	+0.96	0.02	56.0	...	−0.30	...	56.0–105.0
Decalin solution	+0.95[b]	1.00	18.5	+56.5	...	−0.25	18.5–96.5

[a] M.p. determined by X-ray and Kofler methods: 48–52°. [b] c = 1.69.

pentene, (−)(S)-4-methyl-1-hexene and (+)(S)-5-methyl-1-heptene dissolved in hydrocarbon solvents, show molar optical rotation, referred to the monomeric unit, of magnitudes 5 to 28 times greater than the molar optical activity of low molecular weight paraffines, whose structures closely resemble the structure of the monomeric units of the considered polymers.

By fractionation of the crude poly-(S)-3-methyl-1-pentene with different solvents, fractions having different melting points (*i.e.*, different stereoregularity) and different optical activities have been obtained, the specific rotations increasing with increasing stereoregularity (Table I).[4]

The same behavior has been observed for the poly-(S)-4-methyl-1-hexene (acetone extract $[\alpha]^{20}D$ +104°; ether extract $[\alpha]^{20}D$ +268°; isooctane extract $[\alpha]^{20}D$ +278°) and for poly-(S)-5-methyl-1-heptene (acetone extract $[\alpha]^{20}D$ +3.7°; ether extract $[\alpha]^{20}D$ +60°).

The rotation of the poly-(S)-5-methyl-1-heptene insoluble in acetone and showing crystallinity on X-ray examination, has been measured (a) at room temperature, (b) above the melting point, and (c) in dilute decalin solution at different temperatures.

As is shown in Table II, the specific rotation in the solid state and in solution at room temperature are about the same, but the temperature coefficients of the rotation are very different, being very small for the pure polymer below its melting point, but remarkably high for both the molten polymer and for the solution.

The observed temperature depending variations of the rotatory power are completely reversible.

(4) The fractions reported in Table I are different not only in stereoregularity but also in molecular weight; therefore the possible influence of the molecular weight on optical rotation should be in principle considered. Taking in account the results of M. Goodman and E. Schmitt [THIS JOURNAL, **81**, 5508 (1959)] for the poly-γ-methyl-L-glutamate and considering that the acetone soluble fraction of poly-(S)-3-methyl-1-pentene has a number average mol. wt. of 1200 corresponding to about 14 monomeric units, a very remarkable effect of mol. wt. on optical rotation should be excluded.

The high value found for the molar optical rotation of the optically active poly-α-olefins, the increase of the optical rotation with their stereoregularity and the value of the temperature coefficient of their optical rotation in solution, which is much higher than the coefficient found for the low molecular weight paraffins and of the same order of magnitude of some spiralized proteins (Table III) and of the poly-L-glutamic acid,[5] clearly show that the optical rotation in the poly-α-olefins does not arise solely from the existence of asymmetric carbon atoms in the lateral chains.

TABLE III

TEMPERATURE COEFFICIENTS OF THE OPTICAL ROTATION OF SOME LOW MOLECULAR WEIGHT PARAFFINS, OF POLY-α-OLEFINS AND OF SILK FIBROIN

	$[\alpha]D$	t, °C.	$\Delta[\alpha]D/\Delta t$	Temp. interval, °C.
(S)-3-Methyl-hexane[a]	+ 8.78	15.0	−0.009	15.0–71.0
(3S:6S)-3,6-Dimethyloctane[a]	+ 16.85	13.0	.013	74.5–145.5
Poly-(S)-4-methyl-1-hexene[b]	+286	18.0	.66	18.0–97.5
Poly-(S)-5-methyl-1-heptene[c]	+ 56.5	18.5	.25	18.5–96.5
Silk fibroin[d]	+ 43	14	.3	14–41

[a] D. Hardin and S. Sikorsky, *J. Chim. Phys.*, **6**, 179 (1908). [b] Isoöctane extract in tetralin solution. [c] Ether extract in decalin solution. [d] In 1:4 dichloroacetic acid–ethylene dichloride mixture; J. T. Yang and P. Doty, THIS JOURNAL, **79**, 761 (1957).

As the poly-α-olefins we have examined are isotactic or stereoblock polymers, the high optical rotation cannot be ascribed to the asymmetric carbon atoms of the principal chains of the macromolecules.

In order to explain the high optical rotation and its remarkable dependence on stereoregularity and

(5) P. Doty, A. Wada, J. T. Yang and E. R. Blout, *J. Polymer Sci.*, **23**, 851 (1957).

temperature,[6] we suggest that in dilute solution and in the molten state the isotactic and block polymers of optically active α-olefins are at least in part spiralized and that helices of a single screw sense largely prevail.

(6) For the highly stereoregular fractions of poly-(S)-3-methyl-1-pentene which have a very low solubility and high melting point it is possible that the solutions of the polymers still contain crystalline molecular aggregates which undergo dissociation by increasing the temperature. In this case, the decrease of the optical activity by increasing the temperature, could be attributed to the dissociation of the crystalline aggregates having high optical activity to dissolved less optically active macromolecules, which may change or eventually loose their spiralized conformation. G. Natta, M. Farina, M. Peraldo, P. Corradini, G. Bressan and P. Ganis (*Rend. Acc. Naz. Lincei*, April, 1960) have found crystalline molecular aggregates in solutions of some di-isotactic polymers. We are particularly indebted to Prof. Natta and his co-workers for the discussion on this point.

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VIA RISORGIMENTO 19 — G. P. LORENZI
PISA, ITALY

RECEIVED JUNE 4, 1960

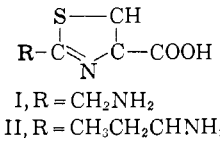
DEGRADATION OF THIOSTREPTON. THIOSTREPTOIC ACID

Sir:

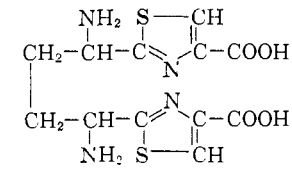
Earlier publications from this Laboratory have described the isolation and characterization[1] as well as the biological properties[2,3] of the antibiotic thiostrepton. Kenner, *et al.*,[4] have isolated the 4-thiazolecarboxylic acids I and II from acid hydrolysates of the antibiotic. This Communication presents our own degradative studies with thiostrepton.

Separation of water-soluble components of acid hydrolysates (6 *N* HCl, 16 hours at 105°) by countercurrent distribution, then partition chromatography, led to the isolation of L-threonine, L-isoleucine, L-alanine, and of D-cystine.[5] The identity of these components was ascertained by comparison with authentic samples on paper chromatograms, by infrared spectra and by measurement of their optical rotation. No other conventional amino acids were found. From a partial hydrolysate (6 *N* HCl at room temperature) L-isoleucyl-L-alanine[6] was obtained in crystalline form and identified by paper chromatographic separation of the components liberated by hydrolysis before and after dinitrophenylation.

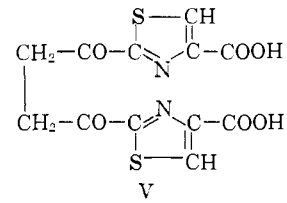
Hydrolysis of thiostrepton with a 1:1 mixture of concentrated hydrochloric and formic acids[7] furnished in addition to the previously isolated[4] thiazolecarboxylic acids[8] I and II,[9] the keto acid III[10] and the hitherto unknown amino acid IV designated by us as *thiostreptoic acid.*



I, R = CH_2NH_2
II, R = $CH_3CH_2CHNH_2$
III, R = CH_3CH_2CO



IV



V

The crystalline acid IV was isolated from the hydrolysate after removal of impurities by butanol extraction. The dihydrate melts at 235–237° (dec.); $[\alpha]^{23}D \pm 0$ (*c*, 1.0 in 1 *N* HCl); $\lambda_{max}^{1N\ HCl}$ 236 mμ (ε = 15,000); *Anal.* weight loss at 110°: 9.7; calcd. for 2 H_2O: 9.5; calcd. for $C_{12}H_{14}O_4N_4S_2$: C, 42.1; H, 4.12; N, 16.4; S, 18.7. Found: C, 42.3; H, 4.21; N, 16.4; S, 18.6. On Whatman No. 1 paper in a system of 1-butanol–acetic acid–water (4:1:1) thiostreptoic acid moves somewhat faster than cystine, R_f = 0.08–0.10. In 1 *N* HCl it forms a crystalline dihydrochloride, which, when dissolved in water, deposits the free acid. Treatment of IV in water with acetic anhydride in the presence of triethylamine yields the corresponding N,N'-diacetyl derivative, m.p. 275–277° (dec.). *Anal.* Weight loss at 110°, 10.4; calcd. for 3 H_2O: 11.2; calcd. for $C_{16}H_{18}O_6N_4S_2$: C, 45.3; H, 4.26; S, 15.1. Found: C, 45.3; H, 4.38; S, 15.1. On both a reaction with dinitrofluorobenzene IV forms mono- and bis-dinitrophenyl derivative.[11] The former is ninhydrin positive. From the specific absorption of the monodinitrophenyl derivative at 355 mμ a molecular weight of about 500 was calculated. Titration of monodinitrophenylthiostreptoic acid with alkali and acid gave neutralization equivalents of 257 and 539, respectively (mol. wt., 508). Reduction of IV with sodium in liquid ammonia and then acid hydrolysis[12] led to a mixture, in which alanine and cystine were identified by paper chromatography. Oxidation of thiostreptoic acid

(1) J. Vandeputte and J. D. Dutcher, "Antibiotics Annual, 1955-1956," Medical Encyclopedia, Inc., New York, N. Y., p. 560.

(2) J. F. Pagano, M. J. Weinstein, H. A. Stout and R. Donovick, *ibid.*, 1955-1956, p. 554.

(3) B. A. Steinberg, W. P. Jambor and Lyda O. Suydam, *ibid.*, 1955-1956, p. 562.

(4) G. W. Kenner, R. C. Sheppard and C. E. Stehr, *Tetrahedron Letters*, 23 (1960).

(5) In thiostrepton this D-amino acid occurs in the reduced form, as shown by the absence of a reaction for disulfides in the antibiotic and the positive test for sulfhydryl after hydrolysis. Moreover, the behavior of this amino acid during fractionation by countercurrent distribution or by partition chromatography was characteristic of cysteine rather than cystine.

(6) Isoleucine and alanine were also found in a diketopiperazine formed during pyrolysis of the antibiotic at 250° *in vacuo*.

(7) G. L. Miller and V. du Vigneaud, *J. Biol. Chem.*, **118**, 101 (1937).

(8) The fact that acid hydrolysis of the product obtained from thiostrepton by reduction with sodium in liquid ammonia yields glycine and α-aminobutyric acid indicates that the thiazolecarboxylic acids I and II, and probably also IV, are present as such in the parent molecule and not, for instance, as thiazolines.

(9) In these studies, II was isolated as a crystalline salt with *p*-hydroxyazobenzene-*p'*-sulfonic acid. *Anal.* Calcd. for $C_{19}H_{20}O_6N_4S_2$: C, 49.1; H, 4.34; S, 13.8. Found: C, 48.9; H, 4.46; S, 13.7.

(10) The acid III, probably formed as a secondary degradation product from II, was found to be identical with the acid isolated by P. Brookes, A. T. Fuller and J. Walker (*J. Chem. Soc.*, 689 (1957)) from *Micrococcin P.* A homologous keto acid was reported as a secondary degradation product from bacitracin A (J. R. Weisiger, W. Hausmann and L. C. Craig, THIS JOURNAL, **77**, 3123 [1955]).

(11) A. R. Battersby and L. C. Craig, THIS JOURNAL, **73**, 1887 (1951); **74**, 4023 (1952).

(12) P. Brookes, R. J. Clark, B. Majhofer, M. P. V. Mijovic and J. Walker, *J. Chem. Soc.*, 925 (1960).