## The Reduction of Ascaridole with Triphenylphosphine[1]

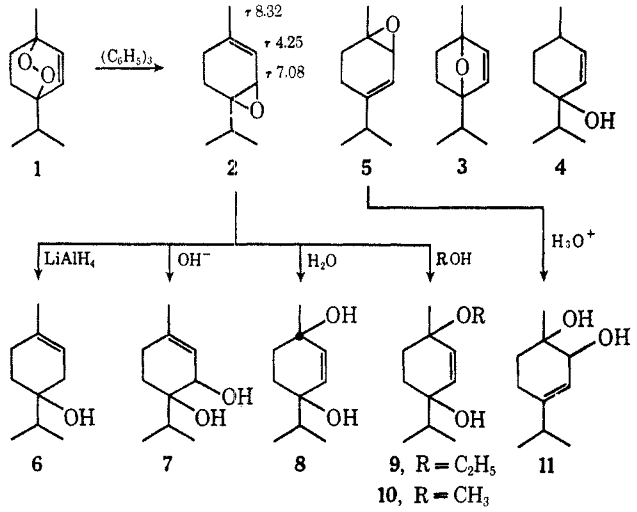
GARY O. PIERSON AND OLAF A. RUNQUIST

*Department of Chemistry, Hamline University, St. Paul, Minnesota 55101*

*Received April 23, 1969*

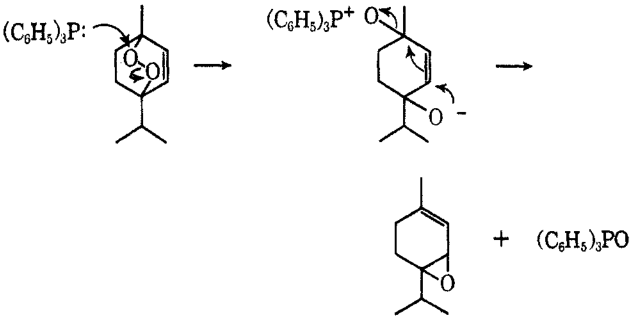
The reduction of ascaridole (**1**) by triphenylphosphine to an unsaturated oxide was first reported by Horner and Jurgeleit.[2] Schenck and coworkers[3] hydrogenated the oxide and obtained an unsaturated alcohol which in turn was reduced to 4-*p*-menthol. On the basis of this information, it was assumed that the oxide was 1,4-epoxy-*p*-2-methene (**3**) and that the unsaturated alcohol was *p*-2-menthene-4-ol (**4**). This paper presents data indicating that the main product resulting from the triphenylphosphine reduction of ascaridole is not **3**, but rather, 3,4-epoxy-*p*-1-menthene (**2**).

The nmr spectrum of the major reduction product of the ascaridole–triphenylphosphine reaction was consistent with structure **2**. The spectrum showed a one-proton multiplet at τ 4.25, appropriate for the C-2 ethylenic proton, a one-proton doublet at τ 7.08, appropriate for the C-3 proton, and a three-proton singlet at τ 8.32, appropriate for a methyl group attached to a double bond. The nmr spectrum also indicated the presence of a second component, which was assumed to be some 1,2-epoxy-*p*-3-menthene (**5**). When the oxide obtained from the triphenylphosphine reduction was treated with $LiAlH_4$, *p*-1-menthene-4-ol (**6**) resulted, and on basic hydrolysis of the oxide, *p*-1-menthene-3,4-diol (**7**) was formed. Treatment of the oxide **2** with water, ethanol, and methanol at 25° resulted in *trans*-*p*-2-menthene-1,4-diol (**8**), 1-ethoxy-*p*-2-menthene-4-ol (**9**), and 1-methoxy-*p*-2-menthene-4-ol (**10**), respectively. The latter products were believed formed by the 1,4 addition of water or alcohol to the unsaturated oxide.[4] When the oil resulting from the reduction of ascaridole with triphenylphosphine was subjected to acid hydrolysis, the only product that could be isolated was a solid identical with *p*-3-menthene-1,2-diol (**11**). This diol was presumably formed from the hydrolysis of some of the 1,2-epoxide present in the reaction mixture.



An attempted reduction of an ethanolic solution of the oxide **2** with hydrogen over Raney nickel yielded the ethoxy alcohol **9**.

The formation of the unsaturated epoxide can be envisioned as a reaction in which one oxygen of the peroxide linkage is displaced by the phosphine to give an ion pair which then rearranges to give the product. A similar mechanism has been postulated by Denny and coworkers[5] for the reduction of diaroyl peroxides.



### Experimental Section

**3,4-Epoxy-*p*-1-menthene (2).**—Thirty grams of ascaridole was allowed to react with 60 g of triphenylphosphine in 100 ml of refluxing petroleum ether (bp 85°) for 15 hr. The product was purified by distillation at reduced pressure: bp 59–62° (3 mm); nmr τ 4.3 (m, 1), 7.1 (d, 1, $J$ = 4 Hz), 7.9–8.3 (m, 5), 8.3 (d, 3, $J$ = 1 Hz), 9.0 (d, 3, $J$ = 7 Hz), 9.1 (d, 3, $J$ = 7 Hz). The nmr spectrum gave evidence of a second component (approximately 8% of the total material) which was assumed to be 1,2-epoxy-*p*-3-menthene.

*Anal.* Calcd for **2**: mol wt (cryoscopic in cyclohexanol), 152. Found: mol wt, 154.

**4-Hydroxy-*p*-1-menthene (6).**—Two grams of the ascaridole–triphenylphosphine reduction product were treated with 0.5 g of $LiAlH_4$ in 25 ml of anhydrous ether. The salts formed were hydrolyzed in 1% HCl and extracted with ether. The ethereal solution was dried and concentrated by evaporation, and the product was purified by column chromatography: nmr τ 4.7 (m, 1), 7.9–8.3 (m, 7), 8.4 (m, 3), 9.18 (d, 3, $J$ = 7 Hz), 9.20 (d, 3, $J$ = 7 Hz), and a one-proton peak of concentration-dependent position.

***p*-1-Menthene-3,4-diol (7).**—Two grams of the ascaridole–triphenylphosphine reduction product were refluxed with 10% NaOH for 17 hr. The mixture was extracted with ether. The ethereal solution was dried and concentrated by evaporation, and the residue was separated by column chromatography. The solid substance obtained was recrystallized from chloroform–petroleum ether C: mp 58–61°; nmr τ 4.4 (m, 1), 6.1 (d, 1, $J$ = 5 Hz), 7.9–8.3 (m, 5), 8.3 (s, 3), 9.0 (d, 3, $J$ = 7 Hz), 9.1 (d, 3, $J$ = 7 Hz), and a two-proton singlet of concentration-dependent position.

***trans*-*p*-2-Menthene-1,4-diol (8).**—A mixture of 5 ml of water and 2 g of the ascaridole–triphenylphosphine reduction product was shaken at room temperature for 24 hr. The crystals (1.7 g, 76%) were collected, dried under vacuum, and recrystallized from chloroform–petroleum ether B: mp 95–96°; nmr ($CDCl_3$) τ 4.2 (s, 2), 7.9–8.3 (m, 5), 8.7 (s, 3), 9.0 (d, 3, $J$ = 7 Hz), 9.1 (d, 3, $J$ = 7 Hz), and a two-proton peak of concentration-dependent position. The infrared spectrum of this compound was not identical with the spectrum of authentic *cis*-*p*-2-menthene-1,4-diol obtained from hydrogenation of ascaridole.

*Anal.* Calcd for **8**: mol wt (cryoscopic in cyclohexanol), 170. Found: mol wt, 163.

---

[1] Abstracted in part from the Senior Thesis of Gary Pierson.

[2] L. Horner and W. Jurgeleit, *Ann.*, **591**, 138 (1955).

[3] G. O. Schenck, K. Gollnick, G. Buchwald, S. Schrocter, and G. Ohloff, *ibid.*, **674**, 93 (1964).

[4] Similar type additions have been observed: V. Bryskovskaya, V. M. Al'bitskaya, and A. A. Petrov, *Zh. Organ. Khim.*, **1** (10), 1898 (1965); E. M. Chamberlin, W. V. Ruyle, A. E. Erickson, J. M. Chemerda, L. M. Aliminosa, R. L. Erickson, G. E. Sita, and M. Tishler, *J. Amer. Chem. Soc.*, **73**, 2396 (1951).

[5] M. A. Greenbaum, D. B. Denny, and A. K. Hoffmann, *ibid.*, **78**, 2563 (1956).

**1-Ethoxy-*p*-2-menthen-4-ol (9).**—A mixture of 5 g of the ascaridole–triphenylphosphine reduction product and 12 ml of absolute ethanol was allowed to stand at room temperature for 3 days. The excess ethanol was removed under reduced pressure and the product was distilled: bp 81–84° (10 mm); nmr ($CDCl_3$) $\tau$ 4.25 (s, 2), 6.55 (q, 2, $J$ = 7 Hz), 8.75 (s, 3), 8.85 (t, 3, $J$ = 7 Hz), 7.8–8.6 (m, 5), 9.05 (d, 3, $J$ = 6 Hz), 9.10 (d, 3, $J$ = 6 Hz), and a one-proton singlet of concentration-dependent position.

*Anal.* Calcd for $C_{12}H_{22}O_2$: C, 72.67; H, 11.18. Found: C, 72.80; H, 10.98.

**1-Methoxy-*p*-2-menthen-4-ol (10).**—A mixture of 2 g of the ascaridole–triphenylphosphine reduction product and 5 ml of methanol was allowed to stand at room temperature for 3 days. The excess solvent was removed under reduced pressure and the product was distilled: nmr (neat) $\tau$ 4.30 (s, 2), 6.85 (s, 3), 7.8–8.6 (m, 5), 8.8 (s, 3), 9.08 (d, 3, $J$ = 7 Hz), 9.13 (d, 3, $J$ = 7 Hz), and a one-proton singlet of concentration-dependent position.

**p-3-Menthene-1,2-diol (11).**—When the ascaridole–triphenylphosphine reduction product was hydrolyzed in 1% $H_2SO_4$ at 0° or in 1% HCl at 35°, a mixture of products resulted. The reaction mixture was neutralized with $NaHCO_3$ and extracted with ether. The ethereal solution was dried, concentrated by evaporation, and separated by column chromatography. One fraction from the chromatographic separation crystallized and was recrystallized from chloroform–petroleum ether B: mp 57–58° (lit.[6] mp 57–58°); the infrared spectrum agreed with that reported in the literature;[5] nmr $\tau$ 4.5 (m, 1), 5.8 (m, 1), 7.9–8.4 (m, 5), 8.8 (s, 3), 9.0 (d, 6, $J$ = 6 Hz), and a two-proton singlet of concentration-dependent position.

**Registry No.**—**1,** 512-85-6; **2,** 21473-34-7; **6,** 562-74-3; **7,** 21473-36-9; **8,** 21473-37-0; **9,** 21473-38-1; **10,** 21473-39-2; triphenylphosphine, 603-35-0.

**Acknowledgment.**—We gratefully acknowledge the financial assistance of the Louis W. and Maud Hill Family Foundation.

(6) T. Matsurra and T. Suga, *J. Org. Chem.*, **30**, 518 (1965).

---

## Phosphorus Pentachloride for the Replacement of Benzylic Hydrogen with Chlorine[1]

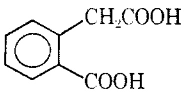
RAYMOND D. KIMBROUGH, JR. AND ROYCE N. BRAMLETT

*Nuclear and Biological Sciences Division, Engineering Experiment Station, Georgia Institute of Technology, Atlanta, Georgia 30332*

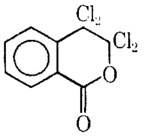
*Received April 10, 1969*

Phosphorus pentachloride has been widely used to replace the hydroxyl groups of alcohols and carboxylic acids to give alkyl chlorides and acyl chlorides, and to replace the carbonyl groups of aldehydes and ketones to give dichlorides.[2]

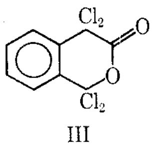
In specific cases, phosphorus pentachloride is known to replace carbon-bound hydrogen. Homophthalic acid, I, with phosphorus pentachloride gives a series of products including II, III, and IV, where replacement of carbon-bound hydrogen with chlorine has occurred.[3]



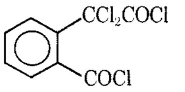
I



II

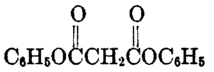


III



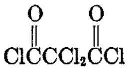
IV

Phenyl malonate, V, and phosphorus pentachloride give a mixture of products including VI and VII where replacement of carbon-bound hydrogen by chlorine has occurred.[4]



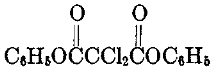
$C_6H_5O\overset{O}{\overset{\|}{C}}CH_2\overset{O}{\overset{\|}{C}}OC_6H_5$

V



$Cl\overset{O}{\overset{\|}{C}}CCl_2\overset{O}{\overset{\|}{C}}Cl$

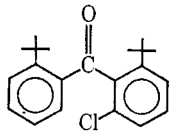
VI



$C_6H_5O\overset{O}{\overset{\|}{C}}CCl_2\overset{O}{\overset{\|}{C}}OC_6H_5$

VII

Chlorination of hydrocarbons, specifically the chlorination of heptane to give heptyl chloride, with phosphorus pentachloride and peroxides has been reported.[5] An aromatic hydrogen is replaced by heating 2,2′-di-*t*-butylbenzophenone and phosphorus pentachloride to 185°, giving VIII.[6]



VIII

In the present work, it has been found that benzylic hydrogen is replaced by chlorine when the material is heated with phosphorus pentachloride. The other products of the reaction are presumably phosphorus trichloride and hydrogen chloride.

The replacement of benzylic hydrogen may proceed by way of a free radical reaction pathway. The first step might be dissociation of the phosphorus pentachloride to phosphorus trichloride and chlorine, a reaction known to occur at elevated temperature.[7] The chlorine would then react at the benzylic position in the familiar manner.[8]

Toluene was converted to benzyl chloride by refluxing with phosphorus pentachloride in almost quantitative yield. With excess phosphorus pentachloride, benzylidene chloride was obtained along with benzyl chloride and unreacted phosphorus pentachloride. Thus the replacement of successive benzylic hydrogen seems to be increasingly difficult.

When diphenylmethane was heated with 1 mol of phosphorus pentachloride, benzhydryl chloride was formed. Excess phosphorus pentachloride gave diphenylmethylene chloride. Triphenylmethane was converted to triphenylmethyl chloride in 93% yield by phosphorus pentachloride at 140–150°.

---

[1] This research was supported by Grant No. ES 00281 from the National Institutes of Health, U. S. Public Health Service.

[2] R. B. Wagner and H. D. Zook, "Synthetic Organic Chemistry," John Wiley & Sons, Inc., New York, N. Y., 1953, pp 91, 105, and 546.

[3] W. Davies and H. G. Poole, *J. Chem. Soc.*, 1616 (1928).

[4] V. I. Shevchenko and A. V. Kirsanov, *Zh. Obshch. Khim.*, **35**, 713 (1965).

[5] B. Fell, *Angew. Chem.*, **77**, 506 (1965).

[6] W. Theilacker and F. Boelsing, *ibid.*, **71**, 672 (1959).

[7] A. F. Holleman and E. Wiberg, "Anorganische Chemie," 32nd ed, Walter de Gruyter & Co., Berlin, 1953, p 254.

[8] D. J. Cram and G. S. Hammond, "Organic Chemistry," Second ed, McGraw-Hill Book Co. Inc., New York, N. Y., 1964, p 523.