unable to isolate *n*-propyl hydroperoxide, although he obtained a good yield of isopropyl hydroperoxide. Harris and Egerton[3] succeeded in preparing *n*-propyl hydroperoxide in yields of only 1.3% per pass. Numerous attempts to prepare *s*-butyl hydroperoxide in our own laboratory following the procedures used by these earlier workers were entirely unsuccessful. We have now found that relatively good yields of *n*- and *s*-butyl hydroperoxides can be obtained by the classical procedure if most of the water employed as reaction solvent is replaced with methanol.

Although the reaction has not been extended to alkyl hydroperoxides higher than butyl, there is an excellent prospect that this improved procedure will prove to be a general one, and it is anticipated that this method may result in improved yields for some of the lower hydroperoxides. The success of the method apparently depends on the fact that methanol brings the alkyl sulfate, hydrogen peroxide and potassium hydroxide into solution in the same phase. Other alcohols and similar solvents may also serve as suitable reaction media.

n-, iso and *s*-butyl hydroperoxides have been previously reported,[4] but properties and methods of synthesis were not included.

Preliminary studies on *n*- and *s*-butyl hydroperoxides indicate that they are relatively stable compounds; detonation was not obtained by hammer blows or by heating with a free flame. In this respect primary and secondary butyl hydroperoxides are more similar to *t*-butyl hydroperoxide than to the relatively unstable methyl and ethyl hydroperoxides.

Experimental

***s*-Butyl Hydroperoxide.**—The preparative procedure employed was similar to that of Harris and Egerton[3] except that a 25% solution of potassium hydroxide in methanol was used in place of the 50% aqueous potassium hydroxide solution. A solution of 1.88 moles of potassium hydroxide in 400 ml. of methanol, chilled and decanted from solid carbonate, was added dropwise to 200 ml. of 30% hydrogen peroxide (2.3 moles) in a three-neck flask equipped with a stirrer. Then 395 g. (1.88 moles) of chilled *s*-butyl sulfate was added dropwise. The reaction mixture was held at −20 to −10° during these additions and then stirred at +2° (ice-bath) for 20 hours. The reaction mixture was added to 2 l. of ice and water; unreacted butyl sulfate was recovered by ether extraction. The aqueous phase was neutralized with 50% sulfuric acid at 0° and 3 pounds of ammonium sulfate was added. The *s*-butyl hydroperoxide was separated by three 200-ml. extractions with ether. Three hundred grams (1.44 moles) of butyl sulfate was recovered and the ether extract of the hydroperoxide contained 0.45 equiv. of peroxide.

Most of the ether was removed at atmospheric pressure from the hydroperoxide fraction; 200 ml. of water was added producing two phases and the mixture was distilled in a three-foot spinning band column at 20:1 reflux ratio and 35 mm. There was obtained 16.2 g. (40% based on butyl sulfate which reacted) of *s*-butyl hydroperoxide as an azeotrope along with an equal volume of water at 30–31°. In other preparations this azeotrope distilled at 36° at 100 mm. and 47° at 150 mm. The azeotropic mixture was saturated with ammonium sulfate and the hydroperoxide layer was dried with anhydrous cupric sulfate; $n^{20}D$ 1.4052, d^{20}_4 0.9094. The active oxygen was determined by reaction with potassium iodide in acetic acid solution.

Anal. Calcd. for $C_4H_{10}O_2$: C, 53.31; H, 11.19; active (O), 17.76. Found: C, 52.13, 52.39; H, 11.26, 10.92; active (O), 16.1, 16.0.

***n*-Butyl hydroperoxide** was prepared in an analogous manner. Eleven ml. (20% yield based on 0.78 moles of reacted *n*-butyl sulfate) was obtained as an azeotrope (b.p. 28–29° at 100 mm.). A heart cut of the hydroperoxide was dried and redistilled at 5 mm.; $n^{20}D$ 1.4032, d^{20}_4 0.9078.

Anal. Calcd. for $C_4H_{10}O_2$: active (O), 17.76. Found: active (O) 16.4, 15.2.

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2-Thienol

BY CHARLES D. HURD AND HUGH J. ANDERSON[1]

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The original synthesis[2] of 2-thienol involved oxidation of a mixture of 2-thienylmagnesium bromide and isopropylmagnesium bromide, the yield being about 25% of the theoretical. The present work describes some new synthetical approaches, but it is interesting to note that none gave yields as high as the original method. These results were obtained.

(a) A 10% yield by treatment of 2-thienyllithium with 1,2,3,4-tetrahydro-1-naphthyl hydrogen peroxide, which method gave a nearly quantitative yield of phenol[3] from phenyllithium. (b) A 5% yield by treatment of a mixture of 2-thienylmagnesium bromide and isopropylmagnesium bromide with 1,2,3,4-tetrahydro-1-naphthyl hydrogen peroxide. (c) No 2-thienol following reaction of 2-thienyldimethylcarbinol in glacial acetic acid with 30% hydrogen peroxide and either aluminum chloride, zinc chloride or titanium tetrachloride. This was adapted from Kharasch's procedure[4] for the preparation of phenol from phenyldimethylcarbinol.

Experimental

Oxidation of 2-Thienyllithium.—A solution of 0.1 mole of 2-thienyllithium[5] in 300 ml. of dry ether was forced through a plug of glass wool into a dropping funnel. It was added slowly, with cooling and stirring, into a solution of 0.05 mole of 1,2,3,4-tetrahydro-1-naphthyl hydrogen peroxide[6] in 100 ml. of dry ether. After standing overnight at −10°, the mixture was poured on Dry Ice and decomposed with dilute sulfuric acid. The ether layer was removed and the aqueous layer was saturated with salt. After two more extractions with ether, the combined ether solutions were washed with three 50-ml. portions of 20% sodium hydroxide solution. The almost black basic solution was cooled and neutralized rapidly with cold dilute sulfuric acid and saturated with salt. This solution was then extracted with four 50-ml. portions of ether, the ether dried and removed to give 1.0 g. of thienol, b.p. 82–87° at 8 mm., a 10% yield. The product was characterized by means of the benzoate, m.p. 43–44°.

The same procedure applied to phenyllithium gave a 75% yield of phenol.

Oxidation of 2-Thienylmagnesium Bromide.—A mixture[2] of 0.1 mole of 2-thienylmagnesium bromide and 0.15 mole of isopropylmagnesium bromide was forced through a plug of glass wool into a dropping funnel. It was then added slowly with stirring and cooling to a solution of 1,2,3,4-tetrahydro-1-naphthyl hydrogen peroxide in 100 ml. of dry ether. After storing overnight at −10° it was processed

(1) The Texas Company Fellow, 1952.

(2) C. D. Hurd and K. L. Kreuz, THIS JOURNAL, **72**, 5543 (1950).

(3) E. Müller and T. Töpel, *Ber.*, **72**, 273 (1939).

(4) M. S. Kharasch, A. Fono and W. Nudenberg, *J. Org. Chem.*, **15**, 748 (1950).

(5) H. Gilman and D. A. Shirley, THIS JOURNAL, **71**, 1870 (1949).

(6) H. Hock and W. Susemihl, *Ber.*, **66**, 61 (1933).

in the same manner as described above to give about 5% yield of 2-thienol.

Treatment of 2-Thienyldimethylcarbinol.—A solution of 5 g. of 2-thienyldimethylcarbinol, prepared in 60% yield by adapting the method of Klages,[7] in 75 ml. of glacial acetic acid was placed in a flask and to it was added 10 ml. of 30% hydrogen peroxide and 0.5 g. of freshly fused zinc chloride. The solution immediately became bright red in color and after 24 hours it was nearly opaque. No thienol was obtained on processing the mixture.

The use of aluminum chloride or titanium tetrachloride instead of zinc chloride also was unsatisfactory.

(7) A. Klages, *Ber.*, **35**, 2633 (1902).

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The Distribution of Triterpenes in Rugel's Plantain[1]

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In connection with a study of the pentacyclic triterpenes and plant sterols now under way in this Laboratory, it appeared of interest to investigate the simultaneous occurrence of these substances and their distribution within various common plants. Zimmermann[2] has stated that only in the dandelion are triterpenes found in all parts of the plant, and Noller[3] has suggested that other plants will be found having a similar distribution. Rugel's Plantain, or *Plantago rugellii*, one of the most prolific weeds in this country, appears from the data presented here to be another such plant. The specimens employed in the present study were obtained from Missouri and Eastern Kansas and were distinguished from the almost identical species *Plantago major* by inspection of the spike.[4]

A chemical study of the alcoholic extracts of the dried and finely ground plant revealed sitosterol (as the sitosterol mixture[5]) as the only sterol present and ursolic acid and oleanolic acid as the triterpenes. The occurrence of these isomeric triterpenes in the same plant appears to be fairly unique, since only a few plants have been reported to contain ursolic and oleanolic acids together.[6-8]

The quantitative distribution of the substances studied is shown in Table I. Ursolic acid and sitosterol occur in all parts of the plant, whether young (before the appearance of seed stalks) or mature. Oleanolic acid, however, was found only in the aereal portions of the mature plant and not at all in the young plant. It appears to us that this constant association of ursolic acid and sitosterol throughout the plant suggests some close metabolic relationship.

TABLE I

RECOVERY OF URSOLIC ACID, OLEANOLIC ACID AND SITOSTEROL FROM *Plantago rugelli*

Plant part	Plant part wt., g.	Yield, g. Ursolic acid	Oleanolic acid	Sitosterol
	Young Plant			
Roots	565	0.9	...	0.8
Leaves	3819	2.3	...	3.8
	Mature Plant			
Roots	1004	0.9	...	1.2
Leaves	2625	5.0	2.0	2.9
Seed stalks	3363	0.5	1.0	0.9
Flower parts	4016	6.0	1.5	4.3

The steroid and triterpenes were isolated by procedures generally used for isolation of sapogenins,[9] and were identified by chemical methods. The absence of oleanolic acid in the young plant was substantiated by a paper chromatographic procedure which will be published at a later date.

Experimental[10]

Preparation and Fractionation of Extracts.—Large quantities of the plant were carefully washed, then dried in air. After sectioning, each part was finely ground and exhaustively extracted with hot, 95% ethanol. The individual extracts were concentrated to low volume and refluxed for two hours in approximately 2 *N* alcoholic HCl. The cooled mixture was diluted with water, extracted with 5% $NaHCO_3$ until the latter was practically colorless, and then with 5% KOH. Oleanolic acid and ursolic acid precipitated out as the K salts during the latter operation. After removal of the precipitate, extraction with 5% KOH was continued until acidification of the extract gave no precipitate. This was essential for complete separation of the carboxylated triterpenes, which tend to remain in the ether at this point.

Isolation of Sitosterol.—The neutral ether fraction was washed with distilled water and evaporated to dryness. It consisted, in each case, principally of orange pigment, a waxy hydrocarbon melting at 72–72.5° (after several crystallizations from methanol) and sitosterol in the form of the sitosterol mixture.[5] Fractionation of this crude product was best effected by chromatography on silica gel prepared according to the method of Gordon, *et al.*[11] The crude product was placed on the column with the help of a little benzene (keeping a ratio of 1/5 of crude product to silica gel) and the column was washed down with low boiling petroleum ether. The first few fractions contained the orange pigment and waxy hydrocarbon. Continued elution with petroleum ether slowly removed the sitosterol; more rapid removal was effected by elution with 2% ethanol in petroleum ether. Two to four crystallizations from methanol served to bring the sitosterol to m.p. 138–140°, not depressed by admixture with an authentic sample of sitosterol mixture from soybean. It gave a characteristic color in the Liebermann–Burchard test. An acetate was prepared from a composite sample from all plant parts by refluxing with acetic anhydride in pyridine; m.p. 127°, not depressed by admixture with an authentic sample of acetate prepared from soybean sitosterol mixture.

Separation of Oleanolic and Ursolic Acids.—The KOH precipitate and KOH extracts were acidified, then extracted with ether. The latter was washed with water and distilled off, leaving a greenish, amorphous mass. The material was placed on a silica gel column (1/5 ratio of crude product to silica gel) with the help of a little warm benzene and eluted with low boiling petroleum ether until waxy solid no longer

(1) Presented before the Division of Biological Chemistry of the American Chemical Society at the autumn meeting held in Atlantic City, N. J., 1952.

(2) J. Zimmermann, *Helv. Chim. Acta*, **26**, 642 (1943).

(3) C. R. Noller, *Ann. Rev. Biochem.*, **14**, 383 (1945).

(4) J. M. Fogg, Jr., "Weeds of Lawn and Garden," Univ. of Penn. Press, Philadelphia, Pa., 1945, p. 159.

(5) L. Fieser and M. Fieser, "Natural Products Related to Phenanthrene," 3rd. Ed., Reinhold Publ. Corp., New York, N. Y., 1949, p. 285.

(6) E. J. Rowe, J. E. Orr, A. H. Uhl and L. M. Parks, *J. Am. Pharm. Assoc.*, **38**, 122 (1949).

(7) T. Bersin and A. Muller, *Helv. Chim. Acta*, **35**, 1891 (1952).

(8) C. Djerassi, *et al.*, THIS JOURNAL, **75**, 2254 (1953), in compiling a list of plant sources of oleanolic acid, were apparently unaware of our Abstract.[1]

(9) R. E. Marker, *et al.*, *ibid.*, **69**, 2167 (1947).

(10) Melting points are uncorrected and were obtained on the Fisher–Johns block.

(11) A. H. Gordon, A. J. P. Martin and R. L. M. Synge, *Biochem. J.*, **37**, 79 (1943).