0.2% or 0.005° for deuterium; 0.3% or 0.007° for tritium. Other sources of error, namely, the radioactive heat (amounting to 8.63×10^{-5} watt/std. cc. of gas[19]) and possible rapid equilibration between ortho and para forms of tritium seem to be inapplicable in the present measurements.

(19) G. H. Jenks, J. A. Ghormley and F. H. Sweeton, *Phys. Rev.*, **76**, 701 (1949).

Summary

1. The vapor pressures of hydrogen, deuterium and tritium have been measured up to three atmospheres.

2. Triple points and heats of vaporization and of sublimation have been derived from the vapor pressures.

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NOTES

Simple Preparation of Optically Active Secondary Alcohols[1]

BY AKSEL A. BOTHNER-BY

It has been well established that reduction of some classes of organic compounds by lithium aluminum hydride is accomplished by transfer of a hydride ion to an electrophilic center of the molecule being reduced.[2] The nature of the ions or neutral molecules donating the hydride ion has not been determined, but a reasonable hypothesis is that in the reduction of a ketone, the forms $Al(OR)_mH_n$ are present, where –OR represents the alkoxyl group derived from the ketone, and m and n are small integers. If this is the case, partial reaction of lithium aluminum hydride with *d*-camphor would give a species capable of asymmetric reduction of ketones. Similar asymmetric reductions have been reported by Vavon and co-workers,[3] Mosher and LaCombe,[4] and Doering.[5] Reductions of methyl ethyl ketone and pinacolone with lithium aluminum hydride–*d*-camphor have been performed. Table I shows for three runs the ketone reduced, the number of moles of lithium aluminum hydride, *d*-camphor and ketone used, and the boiling point and optical activity of the alcohol obtained.

TABLE I

Ketone reduced	Moles $LiAlH_4$	Moles *d*-Camphor	Moles Ketone	Alcohol B.p., °C.	Alcohol $[\alpha]^{25}D$
Methyl ethyl	0.100	0.200	0.200	99.5–100	+2.50
Pinacolone	.118	.118	.354	118–120	+0.04
Pinacolone	.111	.222	.222	118–120	+0.82

Experimental

The reductions were in each case similar to the following: **Optically Active *s*-Butyl Alcohol.**—To a stirred solution of 3.80 g. of lithium aluminum hydride in 300 ml. of ether under nitrogen, was added dropwise a solution of 30.0 g. of *d*-camphor in 50 ml. of ether. Addition required one-half hour. A mixture of 15.0 ml. of methyl ethyl ketone and 50 ml. of ether was then dropped in over one-half hour, followed immediately by 100 ml. of 17% HCl. Stirring was continued until two clear layers were present. The layers were separated, and the ether layer, after drying with calcium chloride pellets, was fractionated through a small Vigreux column. The *d*-isoborneol solidified in the pot. The distillate was refractionated twice to obtain 10.0 g. of *s*-butyl alcohol; $n^{25}D$ 1.3975, b.p. 97–100°, d^{20}_4 0.8084. A subsequent fractionation through a 40-plate column packed with glass helices gave alcohol having $n^{25}D$ 1.3974, b.p. 99.5–100.0°, d^{20}_4 0.8081, $[\alpha]^{25}D$ +2.50°.

BROOKHAVEN NATIONAL LABORATORY
UPTON, LONG ISLAND, N. Y. RECEIVED OCTOBER 9, 1950

(1) Work done under the auspices of the Atomic Energy Commission.

(2) L. W. Trevoy and W. G. Brown, THIS JOURNAL, **71**, 1675 (1949).

(3) (a) Vavon and Angelo, *Compt. rend.*, **224**, 1435 (1947); (b) Vavon, Riviere and Angelo, *ibid.*, **222**, 959 (1946).

(4) Mosher and LaCombe, THIS JOURNAL, **72**, 3994 (1950).

(5) W. von E. Doering, *ibid.*, **72**, 631 (1950).

$\Delta^{5,7}$-Steroids. IV.[1] 7-Dehydrocholesteryl Methyl Ether

BY SEYMOUR BERNSTEIN AND KARL J. SAX

In this note we wish to record the preparation in a pure state of 7-dehydrocholesteryl methyl ether from cholesteryl methyl ether *via* the NBS[2] method.[1,3] This compound has been described previously only in the patent literature,[4] and was prepared by a modified Windaus method.[5]

Cholesteryl methyl ether in petroleum ether was brominated with NBS, and the intermediate bromo compound (not isolated) was dehydrobrominated with *s*-collidine in xylene in the usual manner[1] of this Laboratory. This gave a mixture of the desired $\Delta^{5,7}$-ether and the expected by-product, $\Delta^{4,6}$-cholestadienyl methyl ether. Recrystallization from acetone gave the pure $\Delta^{5,7}$-ether, m. p. 123–125°. This m. p. is in contrast to that given by Rosenberg and Turnbull, Jr.,[4] m. p. 109–111°. Our product was further characterized by optical rotatory power, ultraviolet and infrared absorption spectra (Fig. 1, cholesteryl methyl ether included for comparison purposes).

The material in the mother liquors was triangularly recrystallized from acetone and acetone–methanol. This gave an additional quantity of $\Delta^{5,7}$-ether, and a constant melting mixture of

(1) Paper I, Bernstein, Sax and SubbaRow, *J. Org. Chem.*, **13**, 837 (1948); Paper II, Bernstein, Binovi, Dorfman, Sax and SubbaRow, *ibid.*, **14**, 433 (1949); Paper III, Bernstein, Oleson, Ritter and Sax, THIS JOURNAL, **71**, 2576 (1949).

(2) NBS = N-bromosuccinimide.

(3) Bide and Wilkinson, British Patent 614,194 (Dec. 10, 1948); *C. A.*, **43**, 5810 (1949), have claimed to have prepared several 7-dehydrocholesteryl ethers, *e.g.*, ethyl ether, by the NBS method, but this work is not definitive.

(4) Rosenberg and Turnbull, Jr., U. S. Patent 2,386,636 (Oct. 9, 1945).

(5) Windaus, Lettré and Schenck, *Ann.*, **520**, 98 (1935); Haslewood, *J. Chem. Soc.*, 224 (1938).

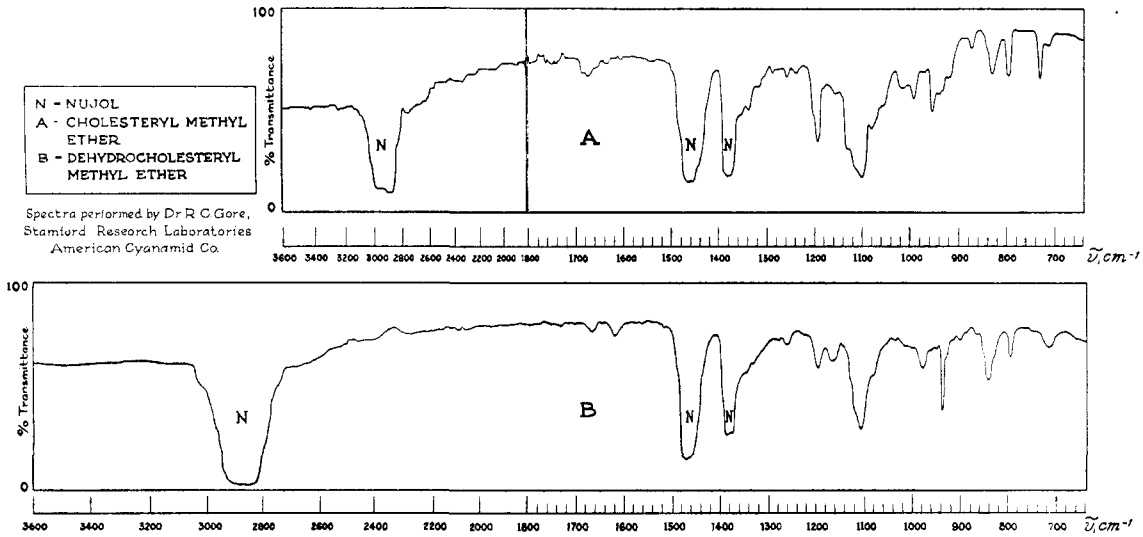

Fig. 1.—Infrared spectra (Nujol mull).

$\Delta^{5,7}$- and $\Delta^{4,6}$-ethers. No further experiment to isolate pure $\Delta^{4,6}$-ether was attempted.

Experimental

7-Dehydrocholesteryl Methyl Ether.—A mixture of 8.0 g. (0.02 *M*) of cholesteryl methyl ether and 4.28 g. (0.024 *M*) of NBS in 100 ml. of petroleum ether, b.p. 64–66° (purified with concd. sulfuric acid and potassium permanganate) was refluxed and irradiated for 3.5 minutes by the heat and light of 2 photospot lamps (type RSP-2, General Electric Co.). Eight ml. of *s*-collidine was then added to the refluxing mixture, which was cooled and filtered. The filtrate was evaporated *in vacuo* (nitrogen atmosphere); the distillation temperature was maintained at room temperature and below. Eighty ml. of xylene was added to the residue. The mixture was refluxed for 12 minutes (nitrogen atmosphere), cooled, and the solid was separated by filtration. The filtrate on evaporation *in vacuo* (nitrogen atmosphere) gave an oily residue which crystallized on treatment with acetone; wt. 5.06 g., m.p. 83–109°; $\lambda_{max.}^{1\%\ CA}$[6] 240, 272, 282 and 294 mμ; ϵ_{240} = 9050, ϵ_{282} = 6360. Six recrystallizations to constant melting point from acetone gave the pure $\Delta^{5,7}$-ether, wt. 0.76 g., m.p. 123–125°; $\lambda_{max.}^{1\%\ CA}$ 272, 282 and 294 mμ; ϵ_{272} = 9900, ϵ_{282} = 10600, ϵ_{294} = 5950; $[\alpha]^{27}D$ −104.3° (19.55 mg. in 2 ml. of chloroform, 1 dcm. semi-micro tube, gave $\alpha^{27}D$ −1.02°), $[M]_D$ −415.

Anal.[7] Calcd. for $C_{28}H_{46}O$ (398.65): C, 84.35; H, 11.63; OCH_3, 7.78. Found: C, 84.19; H, 11.80; OCH_3, 7.99.

The material in the mother liquors was triangularly recrystallized from acetone and acetone–methanol, and gave an additional 0.26 g. of the $\Delta^{5,7}$-ether, m.p. 122–124°, and two fractions consisting of a mixture of $\Delta^{4,6}$- and $\Delta^{5,7}$-ethers, m.p. 86.5–88.5° and 86–88°, $\lambda_{max.}^{1\%\ CA}$ 239, 271.5, 282 and 293–294 mμ.

(6) Solvent was 1% chloroform–absolute alcohol; the substance was dissolved in 1 ml. of chloroform and rapidly diluted to 100 ml. with absolute alcohol.

(7) We are indebted to Messrs. Louis M. Brancone and Samuel M. Modes for the microanalytical data.

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The Reduction of Estrone and Estrogen Esters

BY JOHN H. BIEL

Difficultly hydrolyzable esters of β-estradiol have been shown to possess a greater clinical usefulness than β-estradiol itself.[1] It was desirable therefore to develop a process for the reduction of highly branched esters of estrone to the corresponding β-estradiol 3-esters. Various hydrogenation procedures for estrone and its esters have been described in the chemical and patent literature. Thus Miescher and Scholz[2] were able to reduce aliphatic esters of estrone to estradiol 3-esters by catalytic hydrogenation in ethyl acetate. Marker and Rohrmann[3] converted the trimethylacetate and *t*-butylacetate of estrone to the corresponding β-estradiol derivatives with Adams catalyst in neutral medium at atmospheric pressure and room temperature. Estrone has also been reduced by means of lithium aluminum hydride[4] to β-estradiol and by aluminum isopropoxide[5] to a mixture of β-estradiol and α-estradiol.

While estrone esters could be reduced successfully by catalytic hydrogenation, the method was impracticable for our purpose. Both lithium aluminum hydride and calcium hydride cleaved the esters to β-estradiol and estrone, respectively, during hydrogenation even under mild conditions (see Experimental). Dirscherl[6] reported a similar cleavage of estrone esters during catalytic reduction.

The use of sodium borohydride for the reduction of aldehydes, ketones and acid chlorides was first reported by Chaikin and Brown.[7] We found that this reagent afforded a simple and convenient method for obtaining β-estradiol and two of its highly branched aliphatic esters in excellent yield and high purity from estrone and the corresponding estrone esters. Estrone esters where the acid moiety did not contain a highly branched side chain such as the acetate, propionate, butyrate and benzoate yielded either β-estradiol or a mixture of prod-

(1) W. Brown and J. T. Bradbury, *J. Clin. Endocrinol.*, **8**, 612 (1948).

(2) K. Miescher and C. Scholz, U. S. Patent 2,156,599 (1939).

(3) R. E. Marker and E. Rohrmann, THIS JOURNAL, **61**, 1922 (1939).

(4) A. C. Ott and M. F. Murray, Abstracts of the 113th Meeting of the American Chemical Society, April, 1948.

(5) R. E. Marker and E. Rohrmann, THIS JOURNAL, **60**, 2927 (1938).

(6) W. Dirscherl, *Z. physiol. Chem.*, **239**, 53 (1936).

(7) S. W. Chaikin and W. G. Brown, THIS JOURNAL, **71**, 122 (1949).