20, respectively. *N*-2,2,2-Trifluoroethyl ethyl urethane was prepared by treating at room temp. an ethereal solution of the amine with $^1/_2$ equivalent of ethyl chlorocarbonate. The amine hydrochloride was removed by filtration and the urethane recovered by evaporation of the solvent and sublimed.

2,2,2-Trifluoroethyltrimethylammonium bromide. Equimolar amounts of methyl bromide and dimethyltrifluoroethylamine were measured gasometrically and condensed by means of liquid nitrogen into an evacuated tube. The tube was then stored at ambient temps. for several hours. Reaction was essentially quantitative and appeared to occur entirely in the liquid phase.

2,2,2-Trifluoroethyltrimethylammonium iodide. A from dimethyltrifluoroethylamine. The reaction was carried out in the same manner with methyl iodide as with methyl bromide. Solutions of the quaternary iodide were found to liberate iodine quite readily on contact with the air. *B from trifluoroethyl iodide.* Trifluoroethyl iodide[16] (2.10 g., 0.01 mole) and 1095 ml. at 24.5° and 407 mm. (0.24 mole) of trimethylamine were sealed in an evacuated, heavy walled, Pyrex tube of about 9 ml. capacity and stored at ambient temp. for 12 days. The tube was then opened and its volatile contents pumped off. Approximately 120 mg. of solid residue remained.

Methyl-2,2,2-trifluoroethylnitrosamine. To a solution of 37.5 g. (0.25 mole) of methyltrifluoroethylamine hydrochloride in 140 ml. of 10% HCl was added with stirring a solution of 17.5 g. (0.25 mole) of 95% $NaNO_2$ in 75 ml. of water. The temp. was kept below 10° by external cooling during the addition and for an additional hour thereafter. The oily lower layer was separated, and the aqueous phase was extracted 5 times with 25 ml. portions of CH_2Cl_2. After drying over anhyd. Na_2SO_4 the clear yellow solution was distilled to yield, after a CH_2Cl_2 forerun, 26.5 g. (74.5%) of bright yellow nitrosamine, b.p. 131–133°, $d_{22.5}$ 1.287, n_D^{25} 1.36714. Its infrared spectrum shows bands at 6.78, 7.46, 7.93, 8.55, 9.07, 9.64, 12.01, and 13.27μ.

Methyl-2,2,2-trifluoroethylnitramine. The nitrosamine was oxidized by the method of Emmons, Procedure A[13], in 43% yield. The nitramine is a colorless liquid boiling at 76–78°/33 mm., d_{22} 1.400, n_D^{25} 1.38893. Its infrared spectrum shows bands at 6.43, 6.87, 7.14, 7.42, 7.65, 7.92, 8.13, 8.57, 9.11, 9.75, 12.05, 13.07, and 14.22μ.

Acknowledgments. The authors are indebted to Dr. Allan Zalkin and Mr. Vernon G. Silveira for the x-ray analysis and to Drs. Ann P. Werbin and Russell Sanborn for some of the infrared spectra. The elementary analyses were performed by the University of California Microchemical Laboratory, Berkeley, Calif.

LIVERMORE, CALIF.

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[16] Columbia Organic Chemicals Co., Inc., 912 Drake St., Columbia, S. C.

[CONTRIBUTION FROM THE LAWRENCE RADIATION LABORATORY, UNIVERSITY OF CALIFORNIA]

Organic Deuterium Compounds. II. Some Deuterated Tetrahydrofurans[1]

EUGENE R. BISSELL AND MILTON FINGER

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The synthesis and some of the physical properties of tetrahydrofuran-2,2,5,5-d_4, tetrahydrofuran-3,3,4,4-d_4, tetrahydrofuran-2,3,4,5-d_4 and tetrahydrofuran-d_8 are reported. The vapor pressure of tetrahydrofuran was also measured.

As part of a continuing program on the preparation and properties of deuterated organic compounds, we have prepared and measured some of the physical properties of tetrahydrofuran-2,2,5,5-d_4, tetrahydrofuran-3,3,4,4-d_4, tetrahydrofuran-2,3,4,5-d_4 and tetrahydrofuran-d_8. Since comparison data for some of the physical properties reported of tetrahydrofuran itself were not available, they were also measured.

Tetrahydrofuran-2,2,5,5-d_4 was prepared by lithium aluminum deuteride reduction of diethyl succinate followed by cyclization in the presence of phosphoric acid.[2] In preliminary experiments with undeuterated materials it was found unnecessary and even impractical to purify the intermediate 1,4-butanediol because of its viscosity and high boiling point. Some dehydration of the intermediate glycol to allyl alcohol was also observed during the cyclization. In a like manner tetrahydrofuran-3,3,4,4-d_4 and tetrahydrofuran-d_8 were prepared from dimethyl succinate-d_4[3] by reduction with lithium aluminum hydride and lithium aluminum deuteride, respectively, followed by cyclization. Preparation of tetrahydrofuran-3,3,4,4-d_4 by reduction of 1,4-butynediol with deuterium gas, at 4 to 5 atmospheres in the presence of platinum, followed by phosphoric acid cyclization, resulted in material containing only about 48% of the β-hydrogen atoms replaced by deuteriums.

Tetrahydrofuran-2,3,4,5-d_4 was prepared by catalytic reduction (5% rhodium on alumina) of furan in an atmosphere of deuterium. Of the series of compounds prepared this is the only one which can exhibit stereoisomerism. Although the physical properties presented here cannot be used to distinguish which isomer or isomers may be present, the method of preparation renders some of them more probable than others. Catalytic hydrogenation is generally accepted to add hydrogens in pairs *cis* to one another.[4,5] With a diene system

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[1] This work was done under the auspices of the U. S. Atomic Energy Commission.

[2] W. Reppe, U. S. Patent **2,251,292,** August 5, 1941.

[3] A. McLean and R. Adams, *J. Am. Chem. Soc.*, **58,** 804 (1936).

[4] A. Farkas and L. Farkas, *Trans. Faraday Soc.*, **33,** 837 (1937).

three possible modes of addition of the pairs exists: (1) addition of two pairs before the substrate is desorbed, (2) addition of one pair, 1,2, followed by desorption and readsorption before addition of the second pair, or (3) addition of one pair, 1,4, followed by desorption and readsorption before addition of the second pair. If all four deuterium atoms are added to the diene system before the substrate is desorbed, all four of the deuterium atoms would be expected to be *cis* to one another, thus forming a single isomer, namely, tetrahydrofuran-2α,3α,4α,5α-d_4. If two deuteriums are added, 1,2, followed by desorption, readsorption should occur with the attached deuterium pair either adjacent to or opposite from the catalyst surface with respect to the ring with approximately equal probability; therefore two stereoisomers are possible, namely tetrahydrofuran-2α,3α,4α, 5α-d_4 and tetrahydrofuran-2α,3α,4β,5β-d_4. Likewise if two deuteriums are added, 1,4, followed by desorption, two isomers are again possible, namely, tetrahydrofuran-2α,3α,4α,5α-d_4 and tetrahydrofuran-2α,3β,4β,5α-d_4. Therefore, of the six possible stereoisomers, one, tetrahydrofuran-2α,3α,4α,5α-d_4, is undoubtedly present, and two others, tetrahydrofuran-2α,3α,4β,5β-d_4 and tetrahydrofuran-2α,3β,4β,5α-d_4, may also occur.

The isotopic purity of the deuterated compounds was estimated separately for the α- and β-carbon atoms by comparison of nuclear magnetic resonance spectra. Table I lists these estimates. The estimate for the d_8 isomer was verified by quantitatively burning a sample and converting the water produced to hydrogen gas. Mass spectral analysis showed it to be 96.7% and D3.3% H.

TABLE I

ISOTOPIC COMPOSITION OF DEUTERATED TETRAHYDROFURANS

Compound	% D on α-Carbon	% D on β-Carbon
2,2,5,5-d_4	96 ± 2	0
3,3,4,4-d_4	0	98 ± 2
2,3,4,5-d_4	52 ± 2	48 ± 2
-d_8	98 ± 2	98 ± 2

The constants *A* and *B* for the Antoine vapor pressure equation, $\log_{10} P = A - B/(t + C)$ (P in mm. of Hg., t in °C., and $C = 225$), together with the normal boiling point, melting point, and index of refraction for tetrahydrofuran and its deuterated analogs are listed in Table II.

EXPERIMENTAL

Tetrahydrofuran-2,2,5,5-d_4. A solution of 23.6 g. (0.16 mole) of freshly distilled diethyl succinate in 100 ml. of sodium-dried ether was added over a period of 1 hr. under an argon atmosphere to a stirred suspension of 6.27 g. (0.16 mole) of lithium aluminum deuteride[6] in 100 ml. of sodium-dried ether at 0°. After the addition was complete, the reaction mixture was heated under reflux with stirring for 3 hr. Water (40 ml.) was added cautiously to the stirred reaction mixture (at 0°). After stirring at ambient temperature for 1 hr., the ether layer was decanted and used to extract the solid residue for 24 hr. in a Soxhlet extractor. The solvents were removed by distillation at atmospheric pressure through a 15-in. Vigreux column. The receiver of the column was then connected through a trap to a vacuum manifold, and the entire assembly was evacuated to about 10μ pressure for 4 hr. Air was then admitted to the column to 1 atmosphere pressure, and 1.0 ml. of 85% orthophosphoric acid was added to the pot. After heating under total reflux for 1 hr., all material boiling below 100° at atmospheric pressure was distilled into the receiver and then transferred with the aid of liquid nitrogen to the trap. The bulk of the water was removed from the distillate by twice distilling it through a −36° trap on the vacuum manifold followed by treatment with drierite. The yield was about 65%. After a final drying over sodium wire it was fractionated on a 90-cm. spinning band column at a reflux ratio of 30 to 1.

Tetrahydrofuran-2,3,4,5-d_4. Freshly distilled furan (30 ml., 28.2 g., 0.41 mole) containing 0.3 g. of 5% rhodium on alumina catalyst[7] was shaken at 27° in an atmosphere of deuterium[8] in a 500-ml. Parr high-pressure hydrogenation bomb. From an initial pressure of 800 p.s.i.g. deuterium uptake was complete in about 2 hr. The catalyst was removed by filtration, and the filtrate was carefully fractionated on a 90-cm. spinning band column at a reflux ratio of 30 to 1. The yield was essentially quantitative.

Vapor pressures. Vapor pressures were measured over the temp. range 20° to 68° by the use of an isoteniscope

TABLE II

PHYSICAL CONSTANTS FOR DEUTERATED TETRAHYDROFURANS

Compound	*A*	*B*	% Dev.	N.B.P.	M.P.	$n_D^{25.0}$	$n_D^{29.4}$	Δn_D/°C.
-h_8[a]	6.88463	1166	0.18	66.2	−107.9	1.40444	1.40249	−0.00044
2,2,5,5-d_4	6.89888	1169	0.25	65.9	−109.1	1.40302	1.40084	−0.00049
3,3,4,4-d_4	6.89073	1164	0.32	65.3	−105.8	1.40267	1.40085	−0.00041
2,3,4,5-d_4	6.82768	1146	0.24	65.4	−107.7	1.40209	1.39985	−0.00050
-d_8	6.89256	1165	0.22	65.4	−105.6	1.40146	1.39891	−0.00057

[a] N. I. Shuikin and E. M. Chilikina, *J. Gen. Chem.* (U.S.S.R.), **6**, 279 (1936), report b.p. 65–65.2/746 mm., n_D^{20} 1.409; The E. I. du Pont Co., Electrochemicals Dept. reports in *Chem. and Eng. News*, July 7, 1958, p. 18, freezing point −108.52°, n.b.p. 65°; F. Klages and K. Mohler, *Chem. Ber.*, **81**, 411 (1948), report n.b.p. 62–63°.

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(5) K. N. Campbell and B. K. Campbell, *Chem. Rev.*, **31**, 147 (1942).

(6) Metal Hydrides, Inc., 12–24 Congress Street, Beverly, Mass. According to the manufacturer this material was 98+% D.

(7) Baker and Co., Inc., 113 Astor St., Newark 5, N. J., lot No. 3537.

(8) 98.22% D_2, 1.42% DH, 0.08% H_2, and 0.29% N_2 by mass spectrometer. We are indebted to Dr. Amos Newton for this analysis.

similar to that described by Weissberger.[9] The sample was introduced into the evacuated and outgassed isoteniscope and outgassed to constant vapor pressure at 20° through a bypass which was later sealed off. Mercury was used in the U-tube rather than the liquid under investigation because of the high solubility of the latter in all of the common stopcock greases. Both the mercury levels in the U-tube and in the mercury manometer were observed by means of a cathetometer to ±0.1 mm. The temperature was obtained by means of a rapidly stirred water bath, which was contained in a clear-walled Dewar flask and was observed by means of an Anschutz melting point thermometer to ±0.1°.

Melting points. The melting points listed in Table II were determined by suspending samples sealed in evacuated pyrex tubes of about 5 mm. o.d. and 15 cm. long in a rapidly stirred ethanol-ether bath contained in a half-gallon Dewar flask. The bath was cooled with liquid nitrogen sufficiently below the melting point to cause the samples to crystallize. They tended to supercool by 20-30°. Heating was accomplished by natural conduction at a rate slightly less than 1°/min. Temperatures were measured with an iron-constantan thermocouple and a 10-mv. Varian model G-10 recorder.[10]

Acknowledgment. The authors are indebted to Dr. Bert E. Holder for the nuclear-magnetic resonance determination of D/H ratios, to Mr. Richard W. Crawford for burning a sample of our tetrahydrofuran-d_8 and to Miss Patricia A. Cogswell for its mass spectral analysis.

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(9) A. Weissberger, *Physical Methods of Organic Chemistry*, Interscience Publishers, Inc., New York, 1949, Vol. I, Part I, pp. 173-5.

(10) Varian Associates, Palo Alto, Calif.

[CONTRIBUTION FROM THE KEDZIE CHEMICAL LABORATORY, MICHIGAN STATE UNIVERSITY]

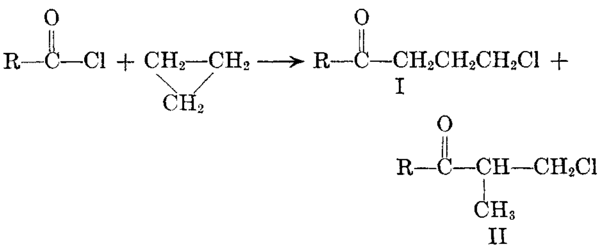
Cyclopropane Chemistry. VI. Acylation of Some Substituted Cyclopropanes[1,2]

HAROLD HART AND GEORGE LEVITT

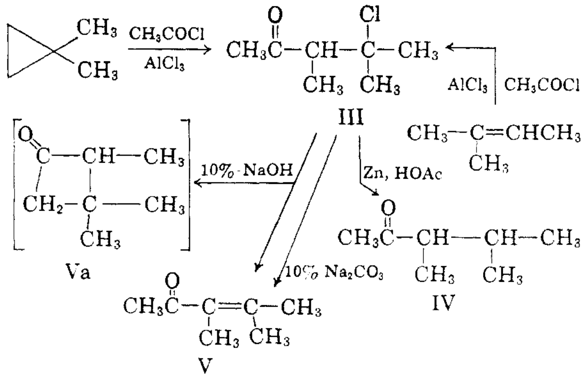
Received March 10, 1959

A previously reported[3] rearrangement in the acylation of cyclopropanes has been confirmed and extended to certain substituted cyclopropanes. 1,1-Dimethylcyclopropane and acetyl chloride gave mainly 4-chloro-3,4-dimethyl-2-pentanone (III). Chlorocyclopropane and acetyl chloride gave, after dehydrohalogenation of the initial product, 4-chloro-3-methyl-3-butene-2-one (VII). Both of these products are branched chain β-chloroketones; no products corresponding to "normal" addition (*i.e.*, γ-chloroketones) were identified. Chloracetyl chloride and cyclopropane gave both the normal product [1,5-dichloro-2-pentanone (XI)] and, after dehydrohalogenation 1-chloro-3-methyl-3-butene-2-one (XII) corresponding to the β-chloroketone or abnormal product. Acetylation of the phenyl ring predominated with phenylcyclopropane, *p*-cyclopropylacetophenone being isolated in good yield. Acetyl perchlorate in nitromethane was not a satisfactory acetylating agent for cyclopropanes. 1,1-Dichlorocyclopropane was acetylated only slowly in refluxing chloroform, several sulfonyl halides were unreactive toward cyclopropane, and *t*-butyl chloride and cyclopropane gave a mixture of C_7 alkyl chlorides in poor yield.

The acylation of cyclopropane was recently shown[3] to take a rather unusual course, for in addition to the anticipated γ-chloroketones (I), there were also obtained β-chloroketones with a branched structure (II). Indeed, products with the latter structure predominated; the ratio of II/I was approximately 2 when R = ethyl, isopropyl, or phenyl. Previous studies[3] were limited to cyclopropane itself, and to lower acyl halides and benzoyl chloride. In the present work, the reaction is extended to several substituted cyclopropanes to determine the direction of ring opening, and to certain additional acylating agents.



1,1-Dimethylcyclopropane. A single chloroketone, which proved to be 4-chloro-3,4-dimethyl-2-pentanone (III), was obtained (crude yield 59%; fractionated, 49%) from the reaction of 1,1-dimethylcyclopropane with a 1:1 acetyl chloride–aluminum chloride complex in chloroform at 0 to



Scheme 1

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(1) For the previous paper in this series, see H. Hart and J. M. Sandri, *J. Am. Chem. Soc.* **81**, 320 (1959).

(2) Taken from a portion of the Ph.D. thesis of George Levitt, 1957.

(3) H. Hart and O. E. Curtis, Jr., *J. Am. Chem. Soc.* **79**, 931 (1957).