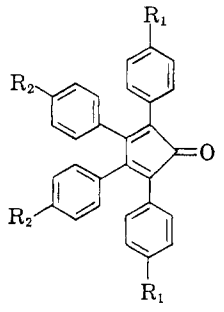
TABLE II

REACTION RATE CONSTANTS



Run No.	R_1	R_2	Temp.	$k \times 10^3$ (molal^{-1} sec.$^{-1}$)
7	H	H	176.4	1.58
8	H	H	176.4	1.57
20	H	H	176.3	1.58
21	H	H	176.3	1.62
			Av.	1.59 ± 0.02
11	Cl	H	176.5	2.42
13	Cl	H	176.3	2.53
15	Cl	H	176.3	2.65
16	Cl	H	176.3	2.50
19	Cl	H	176.3	2.57
			Av.	2.53 ± 0.07
10	H	Cl	176.3	2.37
12	H	Cl	176.3	1.93
14	H	Cl	176.3	2.17
17	H	Cl	176.3	2.38
18	H	Cl	176.3	2.07
			Av.	2.18 ± 0.15
28	Cl	Cl	176.3	3.10
30	Cl	Cl	176.3	2.98
31	Cl	Cl	176.3	3.33
32	Cl	Cl	176.3	3.13
33	Cl	Cl	176.3	3.30
			Av.	3.17 ± 0.12
34	CH_3O	H	176.3	2.13
35	CH_3O	H	176.3	2.30
36	CH_3O	H	176.3	2.13
37	CH_3O	H	176.3	2.15
			Av.	2.18 ± 0.07
22	H	OCH_3	176.3	1.23
24	H	OCH_3	176.3	1.19
26	H	OCH_3	176.3	1.12
27	H	OCH_3	176.3	1.19
			Av.	1.18 ± 0.03
38	CH_3O	CH_3O	176.3	1.78
39	CH_3O	CH_3O	176.3	1.93
40	CH_3O	CH_3O	176.3	1.70
			Av.	1.80 ± 0.08

phenylpropiolate, $k = 1.48 \times 10^{-3}$ molal^{-1} sec.$^{-1}$ and for methyl 4-chlorophenylpropiolate, $k = 2.25 \times 10^{-3}$ molal^{-1} sec.$^{-1}$. Methoxy substitution in tetracyclone accelerates the reaction when in the *para* positions of the 2- and 5-phenyls, and in all four *para* positions, but decelerates the reaction when in the *para* positions of the 3- and 4-phenyls, whereas the methoxyl group slows the reaction when in the 4- position of methyl phenylpropiolate ($k = 1.10 \times 10^{-3}$ molal^{-1} sec.$^{-1}$). Thus, for the first time it is noted that a halogen may accelerate the Diels-Alder reaction whether in the dienophile or in the diene. The rate-substituent effects observed here are different from those in other Diels-Alder reactions in which no carbon monoxide is lost. For example, it has been shown that the *p*-chloro group has the expected effect of reducing the rate of reaction of 1-phenylbutadiene with maleic anhydride.[14] On the other hand, in the reaction between tetracyclone and methyl phenylpropargylate, the absence of a wall effect[5,6] has been interpreted to mean that the evolution of carbon monoxide is not the rate-determining step in accordance with the concept of Newman.[15] However, the absence of the wall effect has not been demonstrated for substituted tetracyclones and substituted methyl phenylpropargylates.

It is also noteworthy that substitution in tetracyclone affects the reaction to a different extent depending upon the position of substitution in the diene; that is, substitution in the 2,5-phenyls is more activating than substitution in the 3,4-phenyls. These results and those in the preceding paragraph are not easily understood in the present state of knowledge of the reaction. Further work is under way.

DEPARTMENT OF CHEMISTRY
POLYTECHNIC INSTITUTE OF BROOKLYN
BROOKLYN 1, N. Y.

(14) E. J. DeWitt, C. T. Lester, and G. A. Ropp, *J. Am. Chem. Soc.*, **78**, 2101 (1956).

(15) M. S. Newman and E. Coffisch, Jr., *J. Am. Chem. Soc.*, **80**, 830 (1958).

Preparation of Trimethylsilyl Ethers of Hindered 2,4,6-Trialkylphenols

SIDNEY FRIEDMAN, MARVIN L. KAUFMAN, AND IRVING WENDER

Received August 4, 1961

As part of the development of a procedure for preparing the trimethylsilyl ethers of coal and of phenols, we have recently reported the successful preparation of 2,6-di-*t*-butylphenoxytrimethylsilane, using hexamethyldisilazane and trimethylchlorosilane as reagents and pyridine as solvent.[1] Pyridine was chosen because of its very good solvent action on coal, and the observation that it was necessary for derivative formation in the case of 2,6-di-*t*-butylphenol and for complete reaction of coal.

While most phenols will react readily with hexamethyldisilazane, di-*t*-butylphenol requires the presence of pyridine and trimethylchlorosilane as well. At that time,[1] 2,6-di-*t*-butylphenol was the

(1) S. Friedman, M. L. Kaufman, W. A. Steiner, and I. Wender, *Fuel*, **40**, 33 (1961).

most hindered phenol readily available, leading to the conclusion that the system hexamethyldisilazane–trimethylchlorosilane–pyridine was capable of forming the trimethylsilyl ether of any phenol. A subsequent study of 2,4,6-tri-*t*-butyl- and 2,4,6-tri-*t*-amylphenol and of 2,6-di-*t*-butyl-4-methylphenol revealed that substituents in the *para* position of hindered phenols prevented reaction from occurring with this reagent mixture. On the other hand, the trimethylsilyl ether of the unhindered 2,4,6-trimethylphenol is formed by simply refluxing the phenol with hexamethyldisilazane and a trace of trimethylchlorosilane as catalyst, although the catalyst is not necessary.

It was thought that the presence of a base stronger than pyridine would be sufficient to cause reaction of the tri-*t*-alkylphenol. Piperidine was therefore substituted for the pyridine, but reaction still did not take place. A further attempt to form the trimethylsilyl ether of the tri-*t*-butylphenol was made using a recently published[2] procedure which has been successful on carbohydrate derivatives. This method uses trimethylchlorosilane and pyridine as reagents and a two-phase solvent system of hexane and formamide. This procedure also was unsuccessful.

When dimethylformamide, which is neither strongly basic nor strongly acidic, was used as a solvent for the reaction between hexamethyldisilazane and tri-*t*-butylphenol, it proved to be singularly successful. One possible explanation is that in some reaction intermediate, ionic resonance involving charge distribution at the *ortho* and *para* positions of the benzene ring is involved. When the *para* position is vacant, as in 2,6-di-*t*-butylphenol, the charge is free to reside at the *para* position and there be solvated (for example, by pyridine) relatively easily. Resonance stabilization becomes more difficult when no free *ortho* or *para* position is available, especially when the substituents are electronegative alkyl groups, and a solvent with dielectric constant higher than that of pyridine is needed to facilitate solvation of this charge. A similar explanation has recently been proposed[3] to explain the difference in behavior of disubstituted benzenes in different solvents.

Hydrolysis of the trimethylsilyl ethers required the use of alcoholic hydrochloric acid.[1] This is in contrast to the behavior of 2,4,6-trimethylphenoxytrimethylsilane, which is readily hydrolyzed by refluxing with aqueous ethanol.

EXPERIMENTAL

Reagents. The 2,4,6-tri-*t*-butylphenol was generously provided by the Ethyl Corp. The hexamethyldisilazane was prepared by bubbling ammonia through trimethylchlorosilane (Dow Corning) in petroleum ether[4]; that used in later work was purchased from Peninsular Chemresearch Co.

Spectra. Infrared spectra were run on potassium bromide pellets. Ultraviolet spectra were run in cyclohexane.

Preparation of 2,4,6-tri-t-butylphenoxytrimethylsilane. A solution of 5 g. of 2,4,6-tri-*t*-butylphenol, 25 ml. of hexamethyldisilazane, and 25 ml. of trimethylchlorosilane in 30 ml. of dimethylformamide was refluxed under nitrogen for 6 hr. The reaction mixture separated upon cooling into two layers. The upper layer was discarded. The lower layer was extracted with petroleum ether (b.p. 60–68°). The solvent was then evaporated from the extract, leaving 6 g. of crude product. Recrystallization from petroleum ether gave the 2,4,6-tri-*t*-butylphenoxytrimethylsilane, m.p. 85–87.5°.

Anal. Calcd. for $C_{21}H_{38}OSi$: C, 75.45; H, 11.38; Si, 8.38. Found: C, 75.56; H, 11.54; Si, 8.27.

The infrared spectrum of the product showed the absence of the hydroxyl absorption at 2.75 μ and the presence of the trimethylsiloxy absorption bands at 7.9, 8.1, 9.75 (weak), 11.90, 13.20, and 14.60 (weak) μ.[1] Ultraviolet λ_{max} 2791 Å (ϵ 1010), 2726 Å (ϵ 966). Low-voltage mass spectral analysis showed a peak at 334 mass units, with traces (< 1%) of higher and lower molecular weight homologs.

The trimethylsilyl ether formation proceeded satisfactorily in the absence of trimethylchlorosilane but not in the absence of hexamethyldisilazane or dimethylformamide. A catalytic amount of dimethylformamide (0.1 ml.) in the presence of pyridine, hexamethyldisilazane, and trimethylchlorosilane failed to bring about trimethylsilyl ether formation. When oxygen was not excluded during refluxing, considerable oxidation took place.

Preparation of 2,4,6-tri-t-amylphenoxytrimethylsilane. Using a procedure similar to that used for the preceding experiment, 2,4,6-tri-*t*-amylphenoxytrimethylsilane was prepared. This was isolated as a liquid which was recrystallized from ethanol at −20°, yielding a solid, m.p. 24.5–25.5°, with a low-voltage mass spectrum showing a peak at 376 mass units (as well as small amounts of masses 362 and 390), and with characteristic infrared absorption at 7.9, 8.0, 9.47 (weak), 11.90, 13.20, and 14.5 (weak) μ. Hydroxyl absorption at 2.75 μ was absent. Ultraviolet λ_{max} 2797 Å (ϵ 981), 2740 Å (ϵ 930).

Anal. Calcd. for $C_{24}H_{44}OSi$: C, 76.52; H, 11.77; Si, 7.46. Found: C, 76.46; H, 11.75; Si, 8.14.

Preparation of 2,6-di-t-butyl-4-methylphenoxytrimethylsilane. A solution of 5 g. of 2,6-di-*t*-butyl-4-methylphenol (Eastman, recrystallized, m.p. 56°) in 25 ml. of hexamethyldisilazane and 35 ml. of dimethylformamide was refluxed in a nitrogen atmosphere for 14 hr. The solvent and excess reagent were removed by distillation. The residue was chromatographed on alumina, and the main fraction recrystallized from petroleum ether (b.p. 60–68°). This gave 4.5 g. of product, m.p. 122.8–124°, with the characteristic trimethylsiloxy absorption at 8.0, 8.15, 9.75 (weak), 11.9, 13.15, and 14.45 (weak) μ; hydroxyl absorption at 2.75 μ was completely absent. Ultraviolet λ_{max} 2823 Å (ϵ 1127), 2754 (ϵ 1054). Low-voltage mass spectral analysis showed the expected peak at 292 mass units.

Anal. Calcd. for $C_{18}H_{32}OSi$: C, 73.90; H, 11.03; Si, 9.60. Found: C, 74.07; H, 11.19; Si, 10.0.

Hydrolysis of 2,4,6-tri-t-butylphenoxytrimethylsilane. A solution of 1 g. of 2,4,6-tri-*t*-butylphenoxytrimethylsilane in a solution of 6 ml. of concd. hydrochloric acid in 25 ml. of methanol was refluxed for 4 hr. in a nitrogen atmosphere. The reaction mixture was extracted with petroleum ether, and the solvent evaporated. Infrared analysis showed the product to consist entirely of 2,4,6-tri-*t*-butylphenol.

(2) F. A. Henglein and B. Kosters, *Chem. Ber.*, **92**, 1638 (1959).

(3) R. W. Taft, Jr., R. E. Glick, I. C. Lewis, I. Fox, and S. Ehrenson, *J. Am. Chem. Soc.*, **82**, 756 (1960).

(4) S. H. Langer, S. Connell, and I. Wender, *J. Org. Chem.*, **23**, 50 (1958).

Attempts to hydrolyze the trimethylsilyl ether in a pyridine–ethanol–water mixture and in dimethylformamide were unsuccessful.

U. S. DEPARTMENT OF THE INTERIOR
BUREAU OF MINES
4800 FORBES AVE.
PITTSBURGH 13, PA.

Synthesis of Some Derivatives of Ursolic Acid[1]

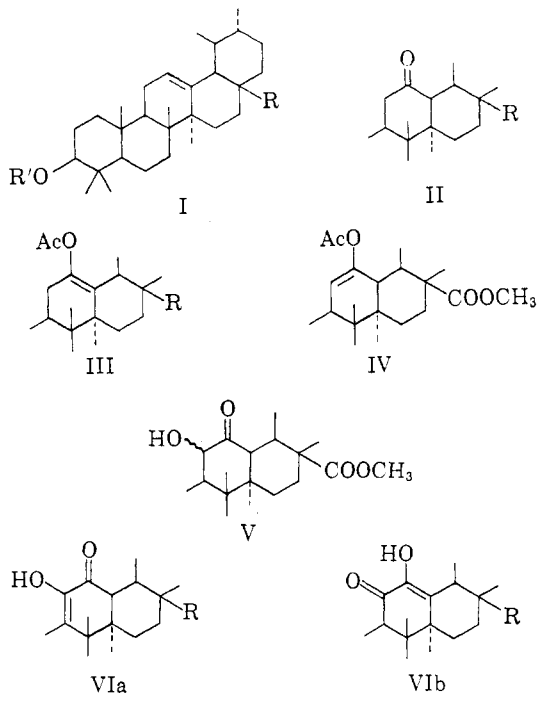
ROBERT A. MICHELI[2]

Received August 7, 1961

Mention of several new derivatives of ursolic acid (I. R′ = H, R = COOH) in a forthcoming publication,[3] which deals with the far ultraviolet absorption spectra of triterpenoids and steroids, makes a description of the synthesis and properties of these compounds timely.

Ursolic acid was isolated from bearberry leaves (*Arctostaphylos uva-ursi*) by the method of Bilham *et al.*,[4] with some modifications. Acetyl methyl ursolate (I. R′ = CH_3CO—, R= $COOCH_3$) was smoothly converted in 79% yield to the saturated, acid labile ketene[5a,b] II (R = $COOCH_3$) by means of peroxytrifluoroacetic acid in the presence of sodium carbonate.[6] Substitution of triethylammonium trifluoroacetate[7] for the carbonate buffer afforded a product different from the desired dihydroketone II (R = $COOCH_3$). This reaction product[8] was only partially characterized and the reaction has not been investigated further.

Conversion of the dihydroketone into the Δ^{12}-enol diacetate III (R = $COOCH_3$) (66% yield) was brought about by the well known sodium acetate–acetic anhydride method.[9] On the other hand, the acid catalyzed reaction of the same unstable dihydroketone with isopropenyl acetate[10] afforded the isomeric Δ^{11}-enol diacetate IV in 83% yield, probably without C-13 epimerization (see ref. 5b for a pertinent discussion of the α-amyrin analogues).



Proton magnetic resonance spectra of the two enol diacetates, taken at 60.0 mc. in deuterated chloroform, were provided by Dr. Robert L. Lundin. That for IV showed a broad singlet having a τ value of 4.58 which is typical of olefinic protons, whereas III showed no such peak.

Oxidation of the highly hindered 12,13-double bond of III (R = $COOCH_3$) with peroxytrifluoroacetic acid in the presence of disodium hydrogen phosphate[6] was not successful. Under similar conditions the Δ^{11}-enol diacetate IV could be readily oxidized to the α-hydroxyketone V. That V was indeed a ketol was established from the infrared spectrum and by oxidation with bismuth oxide in acetic acid to an α-diketone. A study of the ultraviolet and infrared spectra as well as

(1) This work was supported in part by Research Grant CF-4076 from the National Cancer Institute of the National Institutes of Health.

(2) Present address: Western Regional Research Laboratory, U. S. Department of Agriculture, Albany 10, Calif.

(3) R. A. Micheli and T. H. Applewhite, to be published.

(4) P. Bilham, G. A. R. Kon, and W. C. J. Ross, *J. Chem. Soc.*, 35 (1942).

(5) (a) J. L. Simonsen and W. C. J. Ross, *The Terpenes*, Cambridge University Press, London, 1957; see Vol. V, p. 128. The similarity of melting point and optical rotation values make it difficult to distinguish the C-13 epimeric ketones II (R = $COOCH_3$). There seems little doubt that the product from this reaction corresponds to the known unstable ketone since α-amyrin acetate (I. R = CH_3, R, = CH_3CO—) also affords the analogous acid labile ketone with peroxytrifluoroacetic acid–sodium carbonate; (b) I. A. Kaye, M. Fieser, and L. F. Fieser, *J. Am. Chem. Soc.*, **77**, 5936 (1955), discuss the epimeric α-amyrin compounds.

(6) W. D. Emmons and A. S. Pagano, *J. Am. Chem. Soc.*, **77**, 89 (1955).

(7) W. D. Emmons, A. S. Pagano, and J. P. Freeman, *J. Am. Chem. Scc.*, **76**, 3472 (1954).

(8) It has been reported that simple olefins yield hydroxytrifluoroacetates and occasionally ditrifluoroacetates.[7] The crude reaction product from acetyl methyl ursolate gave a negative tetranitromethane color test after 1 or 48 hr. at room temperature; infrared (CS_2), no hydroxyl, 5.56 (CF_3COO—), 5.71 (broad), and 8.04 μ. Hydrolysis was accomplished with potassium bicarbonate in methanol [A. Lardon and T. Reichstein, *Helv. Chim. Acta*, **37**, 388 (1954)]; infrared (CS_2), 2.86 (hydroxyl), 5.72 (broad), and 8.05 μ. In some preliminary studies on Δ^5- and Δ^7-sterols, however, the products appeared to be hydroxytrifluoroacetates; typical infrared (CS_2), 2.9–3.0, 5.60–5.65, 5.78–5.82, and 8.0–8.1 μ. The hydroxyls are readily acetylated at room temperature with acetic anhydride and pyridine.

(9) (a) L. Ruzicka and O. Jeger, *Helv. Chim. Acta*, **24**, 1178 (1941); (b) L. Ruzicka, O. Jeger, J. Redel, and E. Volli, *Helv. Chim. Acta*, **28**, 199 (1945).

(10) H. J. Hagemeyer and D. C. Hull, *Ind. Eng. Chem.*, **41**, 2920 (1949).