To the crude elimination product obtained above was added 50 mL of 5% potassium hydroxide in methanol. After being stirred for 16 h at room temperature, the mixture was poured into water and extracted with methylene chloride. The combined methylene chloride layers were washed with water and brine, dried, and concentrated. Elution from Florisil (50:50 CH_2Cl–C_5H_{12}) gave oily (±)-vetiselinenol (557 mg, 2.53 mmol, 97% yield), identical in all respects with the IR and NMR spectra of a sample of natural (-)-vetiselinenol:[10] IR (neat) 3360 (OH), 1640 (C=C), 890 cm^{-1} (>C=CH_2); NMR (C_6D_6) δ 0.73 (s, 3 H), 1.01 (d, J = 6 Hz, 3 H), 1.93 (s, 4 H), 1.0–2.6 (complex, 9 H), 3.48 (m, 2 H), 4.67 (br s, 1 H), 4.88 (br s, 1 H), 5.37 (br s, 1 H); high-resolution mass spectrum, m/e calcd for $C_{14}H_{21}O$ (M - CH_3) 205.1592, found 205.1618.

Monoacetate 10. In a manner analogous to the preparation of monoacetate **7**, methyl lactone **3** (383 mg, 1.64 mmol) was reduced with lithium aluminum hydride to give 385 mg of crude diol **9**. This material was acetylated without further purification.

The acetylation was carried out as before except that the reaction time was 21 h. Elution of the crude product (497 mg) from Florisil (75:25 CH_2Cl_2–C_5H_{12}) gave oily monoacetate **10** (251 mg, 0.896 mmol, 55% conversion, 79% yield based on recovered diol **9**): IR (neat) 3495 (OH), 1725 (C=O), 1642 (C=C), 1245 (C—O), 885 cm^{-1} (>C=CH_2); NMR (CCl_4) δ 0.92 (s, 3 H), 1.02 (d, J = 6 Hz, 3 H), 2.02 (s, 3 H), 4.00 (m, 3 H), 4.47 (br s, 1 H), 4.68 (br s, 1 H); high-resolution mass spectrum, m/e calcd for $C_{17}H_{26}O_2$ (M - H_2O) 262.1933, found 262.1920.

Further elution of the Florisil column (3:97 Et_2O–CH_2Cl_2) gave crystalline diol **9** (115 mg, 0.483 mmol). Recrystallization from ether–petroleum ether produced white crystals: mp 113.5–114 °C; IR (KBr) 3175 (OH), 1635 (C=C), 885 cm^{-1} (>C=CH_2); NMR (CCl_4) δ 0.93 (s, 3 H), 0.98 (d, J = 6 Hz, 3 H), 3.55 (br s, 2 H), 4.10 (br s, 1 H), 4.47 (br s, 1 H), 4.67 (br s, 1 H). Anal. Calcd for $C_{15}H_{26}O_2$: C, 75.58; H, 10.99. Found: C, 75.40; H, 10.84.

(±)-11-Epivetiselinenol (12). In a manner analogous to the preparation of (±)-vetiselinenol from monoacetate **7**, monoacetate **10** (180 mg) was dehydrated to give a quantitative yield (168 mg) of oily acetate **11** after Florisil chromatography (elution with 10:90 CH_2Cl_2–C_5H_{12}): IR (neat) 1738 (C=O), 1638 (C=C), 1230 (C—O), 886 cm^{-1} (>C=CH_2); NMR (CCl_4) δ 0.68 (s, 3 H), 1.04 (d, J = 7 Hz, 3 H), 1.92 (m, 4 H), 1.95 (s, 3 H), 3.93 (dd, J = 7, 3 Hz, 2 H), 4.53 (br s, 1 H), 4.75 (br s, 1 H), 5.35 (m, 1 H).

The elimination product above was hydrolyzed as before to give (±)-11-epivetiselinenol (140 mg, 0.64 mmol, 100% yield) after Florisil chromatography (elution with 50:50 CH_2Cl_2–C_5H_{12}): IR (neat) 3360 (OH), 1638 (C=C), 887 cm^{-1} (>C=CH_2); NMR (C_6D_6) δ 0.70 (s, 3 H), 0.94 (d, J = 7 Hz, 3 H), 1.90 (s, 4 H), 1.0–2.6 (complex, 9 H), 3.42 (d, J = 7 Hz, 2 H), 4.65 (br s, 1 H), 4.88 (br s, 1 H), 5.37 (m, 1 H); high-resolution mass spectrum, m/e calcd for $C_{14}H_{21}O$ (M - CH_3) 205.1592, found 205.1598.

Acknowledgment. We thank the Committee on Research, University of California, Davis, for partial support of this work. We also thank Professor Niels H. Andersen for supplying samples of natural vetiselinenol and vetiselinene.

Registry No. (±)-**1**, 72257-40-0; (±)-**2**, 54911-04-5; (±)-**3**, 77480-20-7; (±)-**4**, 77480-21-8; (±)-**5**, 4677-48-9; (±)-**6**, 77480-22-9; (±)-**7**, 77415-51-1; (±)-**8**, 77429-54-0; (±)-**9**, 77480-23-0; (±)-**10**, 77480-24-1; (±)-**11**, 77415-52-2; (±)-**12**, 77480-25-2.

Notes

Methanesulfonic Acid Catalyzed Cyclization of 3-Arylpropanoic and 4-Arylbutanoic Acids to 1-Indanones and 1-Tetralones

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Several acidic reagents are available for the preparation of cyclic ketones from 3- and 4-aryl-substituted carboxylic acids.[1] Literature references to the use of methanesulfonic acid (MSA) for this purpose are meager.[2] Eaton and Carlson[3] describe a cyclization procedure using a hot mixture of MSA and P_2O_5. Since MSA ordinarily does not cause sulfonation of aromatic rings, we considered that neat MSA, at elevated temperatures, should be a superior cyclizing reagent because of its acidity and excellent solvent properties. Table I lists the ketones which have been prepared in this study through cyclization of the appropriate carboxylic acid with hot MSA. The performance of neat anhydrous MSA exceeded our expectations and, in some respects, we believe MSA to be superior to hot PPA as a cyclizing agent. It is more convenient to use and requires about the same reaction time and temperature so that these reagents are potentially interchangeable for cyclization. Color changes from yellow to brown to black during the course of the reaction appear to be indicative of the progress of cyclization as was observed by Koo[4] for PPA cyclization reactions. Our studies under a variety of temperatures, concentrations, and reaction times show that 30 min to 3 h is needed for cyclization, depending on the reactivity of the starting material. We noted that 3-arylpropanoic acids generally require about 20 °C higher reaction temperature (110–115 °C) for the same time needed to cyclize 4-arylbutanoic acids at 90–95 °C. We used preheated MSA to better reproduce the reaction time but see no reason why the reaction cannot be started from laboratory temperature. Concentration studies using 3-phenylpropanoic acid showed that yields improved with dilution up to 7 mL of MSA/g of carboxylic acid. Further dilution did not provide a yield increase. We recommend that anhydrous MSA be used and that moisture be excluded during storage and use.

The use of neat MSA as a substitute for Friedel–Crafts catalyst in intermolecular condensation[9] is not promising.

(1) (a) Johnson, W. S. *Org. React.* **1949**, *2*, 114. (b) Fieser, L. F.; Fieser, Mary. "Reagents for Organic Synthesis"; Wiley-Interscience: New York, 1968–1980; Vol. 1–8. (c) Buehler, C. A.; Pearson, D. E. "Survey of Organic Synthesis"; Wiley: New York, 1970 and 1977; Vol. 1 and 2.

(2) (a) Newman, M. S.; Davis, C. C. *J. Org. Chem.* **1967**, *32*, 66. (b) Bodine, R. S.; Hylarides, M.; Daub, G. H.; Vanderjagt, D. L. *Ibid.* **1978**, *43*, 4025.

(3) Eaton, P. E.; Carlson, G. R. *J. Org. Chem.* **1973**, *38*, 4071.

(4) Koo, J. *J. Am. Chem. Soc.* **1953**, *75*, 1891.

(5) Barton, D. H. R.; Sammes, P. G.; Weingarten, G. C. *J. Chem. Soc. C* **1971**, 729.

(6) Agranat, I., Shih, Y. S. *Synthesis* **1974**, 865.

(7) Fieser, L. F.; Johnson, W. S. *J. Am. Chem. Soc.* **1939**, *61*, 168.

(8) Vuppalapaty, P. Ph. D. Thesis, Oklahoma State University, 1979.

(9) This study was carried out at the suggestion of a referee.

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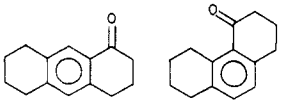
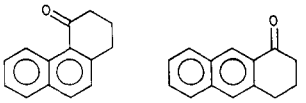
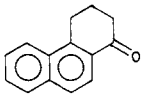
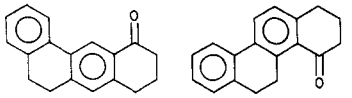
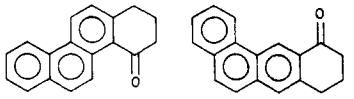
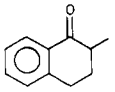
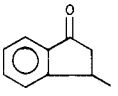
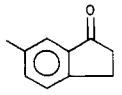
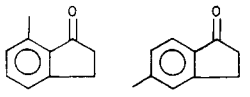
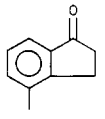
Table I. Products from MSA-Catalyzed Cyclization of 3- and 4-Aryl-Substituted Carboxylic Acids[a]

product(s)	ratio	temp, °C	time, h	% yield
	25:1	90-95	1	95[b]
	100:1	90-95	1	95[c]
		90-95	1	100[d]
	300:1	90-95	1	95[e,f]
	2:1	90-95	1	95[d]
		90-95	1 2	60[d] 90
		90-95	3	89[d]
		90-95 110-115	2 3	20[d] 90
		90-95 110-115	2 3	40[d] 83
		90-95 110-115	2 1.5	28[d] 83
	3:2[g]	90-95 110-115	2 1.5	67[d] 96
		90-95 110-115	2 1.5	62[d] 60

[a] GC (UC W-98) as well as ^1H and ^{13}C NMR studies were used to establish purity, identity, and ratios of products. [b] Reference 5. [c] Reference 6. [d] Reference 1a. [e] Reference 7. [f] Reference 8. [g] PPA gave a 1:1 ratio.

Trial studies in which *m*-xylene was treated with acetic acid in the presence of anhydrous MSA at 110 °C for 3 h gave low yields of acetylation product (ca. 30%). GC analysis of the product showed unreacted *m*-xylene. Increasing the reaction time to 17 h showed that some *m*-xylene remained and considerable tar formed. Naphthalene under similar conditions failed to give an acetylation product. In contrast, Cargill and Jackson[10] have effected intermolecular acylation with MSA containing P_2O_5.

Experimental Section

Cyclization of 3-Phenylpropanoic Acid to 1-Indanone. Methanesulfonic acid[11] (40 mL) was magnetically stirred at 110 °C in a 100 mL, round-bottomed flask equipped with condenser, nitrogen inlet and outlet tube, and thermometer. 3-Phenylpropanoic acid (5.0 g) was added in one batch and the mixture was stirred for 3 h. The dark mixture was poured slowly into 500 g of stirred ice–water and extracted with about 300 mL of ether in two portions. The ether layer was washed with saturated $NaHCO_3$ solution and water, dried ($MgSO_4$), and concentrated to 4.0 g (90%) of crude 1-indanone. This product was distilled (Kugelrohr; 70 °C, 0.4 mm) in 80–85% yield for instrumental studies (Table I).

Except for variation in time and temperature, the ketones of Table I were prepared in an analogous manner.

Condensation of *m*-Xylene and Acetic Acid in the Presence of MSA.[9] *m*-Xylene (5 g, 0.047 mol) and anhydrous MSA (50 mL, 0.79 mol) were combined in a three-neck flask fitted with condenser, thermometer, magnetic stirring bar, and N_2 inlet and heated with stirring to 110 °C. Acetic acid (5.64 g, 0.094 mol) was added and the temperature was maintained for 3 h. The reaction mixture was cooled, added to 200 mL of ice slurry, and then worked up as described above to give 2.5 g of oil. GC analysis (UC W-98 on 80–100 mesh, AW DMCS-treated Chromosorb W) showed *m*-xylene and 2′,4′-dimethylacetophenone in 1:3 ratio. The yield of the latter, corrected for unreacted *m*-xylene, was ca. 30%.

(10) Cargill, R. L.; Jackson, T. E. *J. Org. Chem.* **1973**, *38*, 2125.
(11) We thank the Pennwalt Corporation, Organic Chemicals Division, Philadelphia, PA, for a gift of methanesulfonic acid.

It was identified through ^1H NMR [($DCCl_3$) δ 2.36 (s, 3, $COCH_3$), 2.46 (s, 3, $ArCH_3$ at C-4'), 2.48 (s, 3, $ArCH_3$ at C-2'), 7.02-7.10 (m, 2, Ar H) 7.62 (d, 1, J = 8 Hz, Ar H at C-6')], mass spectrum [m/e 248 (M^+)], and the preparation of the orange 2,4-dinitrophenylhydrazone, mp 168–170 °C [lit.[12] mp 169–170 °C].

Acknowledgment. We thank the Environmental Protection Agency under Grant R805419 and the Bartlesville Energy Technology Center, Department of Energy, under Contract EW-78-A-19-0001 for support. We also thank Dr. G. H. Daub for providing information about his experiences with methanesulfonic acid.

Registry No. 3,4,5,6,7,8-Hexahydro-1(2*H*)-anthracenone, 5440-71-1; 2,3,5,6,7,8-hexahydro-4(1*H*)-phenanthrenone, 13250-73-2; 2,3-dihydro-4(1*H*)-phenanthrenone, 778-48-3; 3,4-dihydro-1(2*H*)-phenanthrenone, 573-22-8; 5,8,9,10-tetrahydrobenz[*a*]anthracen-11-(6*H*)-one, 1470-04-8; 2,3-dihydro-4(1*H*)-chrysenone, 66267-06-9; 9,10-dihydro-11(8*H*)-benz[a]anthracenone, 60968-15-2; 3,4-dihydro-1(2*H*)-naphthalenone, 529-34-0; 2-methyl-3,4-dihydro-1(2*H*)-naphthalenone, 1590-08-5; 2,3-dihydroinden-1(1*H*)-one, 83-33-0; 3-methyl-2,3-dihydroinden-1(1*H*)-one, 6072-57-7; 6-methyl-2,3-dihydroinden-1(1*H*)-one, 24623-20-9; 7-methyl-2,3-dihydroinden-1-(1*H*)-one, 39627-61-7; 5-methyl-2,3-dihydroinden-1(1*H*)-one, 4593-38-8; 4-methyl-2,3-dihydroinden-1(1*H*)-one, 24644-78-8; methanesulfonic acid, 75-75-2; *m*-xylene, 108-38-3; 2',4'-dimethylacetophenone, 89-74-7; 5,6,7,8-tetrahydro-2-naphthalenebutanoic acid, 782-27-4; 2-naphthalenebutanoic acid, 782-28-5; 1-naphthalenebutanoic acid, 781-74-8; 9,10-dihydro-2-phenanthrenebutanoic acid, 7494-59-9; 2-phenanthrenebutanoic acid, 77520-30-0; benzenebutanoic acid, 1821-12-1; α-methylbenzenebutanoic acid, 1949-41-3; benzenepropanoic acid, 501-52-0; β-methylbenzenebutanoic acid, 4593-90-2; 4-methylbenzenepropanoic acid, 1505-50-6; 3-methylbenzenepropanoic acid, 3751-48-2; 2-methylbenzenepropanoic acid, 22084-89-5; 2',4'-dimethylacetophenone 2,4-DNP derivative, 77520-31-1.

(12) Pollock, J. R. A., Stevens, R., Eds. "Dictionary of Organic Compounds", 4th ed.; Oxford University Press: New York, 1965; Vol. 2, p 1135.

Stereoselective, Catalytic Reduction of L-Ascorbic Acid: A Convenient Synthesis of L-Gulono-1,4-lactone

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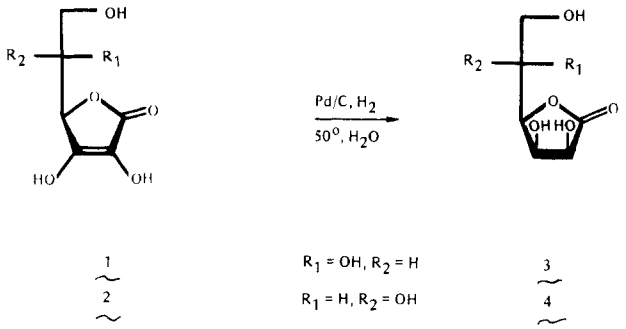
While the chemistry of the derivatization[1] and oxidative degradation[2] of L-ascorbic acid (1) is well documented, its behavior under reductive conditions has been little studied. During early work directed toward the structural elucidation of 1, catalytic reduction over PtO_2 was reported to afford a mixture of products of which only L-idonic acid was identified.[3a] Other workers reported that reduction of 1 afforded a lactone which was not identified further.[3b] More recently it has been reported that catalytic reduction of 1 gave poor results.[2b] 3-*O*-Methyl-L-ascorbic acid has been reported to hydrogenate in the presence of Pd/C to afford a saturated γ-lactone which was assigned the L-manno configuration.[4]



1 ~ 2 ~ R_1 = OH, R_2 = H; R_1 = H, R_2 = OH; 3 ~ 4 ~

During our investigations[5] into different syntheses of 1, we had occasion to determine the stability of 1 to different conditions of catalytic hydrogenation.[6] L-Ascorbic acid was found to be stable to hydrogenation over Raney Ni catalyst at moderate pressure and temperature (50 °C, 50 psi) and, as was previously reported,[3a] to afford a complex mixture of products over Pt catalyst.

However, the hydrogenation of 1 over 10% Pd/C at 50 °C and 50 psi hydrogen pressure resulted in the uptake of the stoichiometric amount of hydrogen to afford, quantitatively, a single new product as evidenced by GLC[7] and ^{13}C NMR of the isolated product. Recrystallization of a sample of this material from methanol–ethyl acetate gave material [mp 182–183.5 (lit.[8] mp 180–181 °C)] identical in spectral and physical characteristics with authentic L-gulono-1,4-lactone (3).

Similarly, D-erythorbic acid (2) under the same conditions affords a single major product in greater than 90% purity (by GLC analysis of the silylated reaction mixture)[7] from which D-mannono-1,4-lactone (4) is isolated in 71% yield [mp 151–151.5 °C (lit.[9] mp 151 °C)] after crystallization from methanol–ethyl acetate. In both cases, the hydrogenation appears to proceed stereoselectively via the delivery of hydrogen from the least hindered side of the enono-lactone moiety opposite the side chain.

These results suggest that the previously reported reduction of 3-*O*-methyl-L-ascorbic acid in fact affords 3-*O*-methyl-L-gulono-1,4-lactone not 3-*O*-methyl-L-mannono-1,4-lactone as reported.[4] The formation of 3-*O*-methyl-L-mannono-1,4-lactone would require delivery of hydrogen both from the more hindered face of the olefin *and* the highly unlikely epimerization at C-4.

Interestingly, both 1 and 2 are unstable to the conditions required for the hydrogenation *in the absence of hydrogen*. Heating 1 or 2 under a nitrogen atmosphere, in water, with Pd/C catalyst results in the disappearance of starting material and the formation of lactone 3 or 4, respectively. In the case of 2, lactone 4 has been isolated in 29% yield after removal of catalyst, neutralization with sodium hydroxide, precipitation of the sodium salt with methanol, and deionization with ion-exchange resin (Dowex-50, H^+ form). The course of the reaction appears to involve the disproportionation of the reductone over the Pd catalyst to neutral oxidized intermediates and hydrogen followed

(1) Tolbert, B. M.; Downing, M.; Carlson, R. W.; Knight, M. K.; Baker, E. M. *Ann. N.Y. Acad. Sci.* **1975**, *258*, 48.
(2) (a) Haworth, W. N.; Hirst, E. L. *Ergeb. Vitam. Hormonforsch.* **1939**, *2*, 1. (b) Jung, M. E.; Shaw, T. J. *J. Am. Chem. Soc.* **1980**, *102*, 6304.
(3) (a) Michael, F.; Kraft, K. *Z. Physiol. Chem.* **1933**, *222*, 235. (b) Levene, P. A.; Raymond, A. L. *Science* **1933**, *78*, 64.
(4) Radford, T.; Sweeny, J. G.; Iacobucci, G. A.; Goldsmith, D. J. *J. Org. Chem.* **1979**, *44*, 658.
(5) Andrews, G. C.; Bacon, B.; Crawford, T. C.; Breitenbach, R. *J. Chem. Soc., Chem. Commun.* **1979**, 740. Crawford, T. C.; Breitenbach, R. *Ibid.* **1979**, 388.
(6) Reaction conditions which would be desirable for several syntheses of 1: Kitahara, T.; Ogawa, T.; Naganuma, T.; Matsui, M. *Agric. Biol. Chem.* **1974**, *38*, 2189; Bakke, J.; Theander, O. *J. Chem. Soc., Chem. Commun.* **1971**, 176.
(7) Dried aliquots of the reaction mixture were silylated with Tri-Sil TBT (Pierce Chem. Co.) and analyzed by GLC (2-m 3% OV-210 column at 155 °C).
(8) Berends, W.; Konings, J. *Recl. Trav. Chim. Pays-Bas* **1955**, *74*, 1365. Ishidate, M.; Imai, Y.; Hirasaka, Y.; Umemoto, K. *Chem. Pharm. Bull.* **1965**, *11*, 1973.
(9) Heynes, K.; Stöckel, O. *Justus Liebigs Ann. Chem.* **1947**, *558*, 192. Nelson, W. L.; Cretcher, L. H. *J. Am. Chem. Soc.* **1930**, *52*, 403.

0022-3263/81/1946-2976$01.25/0