Preparation of 1-Carboxybicyclo[4.3.1]dec-3-en-10-one

RICHARD D. SANDS

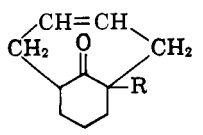
Department of Chemistry, Alfred University, Alfred, New York

Received September 9, 1963

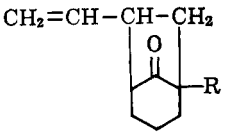
The preparation of bicyclo[4.3.1]dec-7-en-10-one[1] stimulated an interest in the preparation of related bicyclic compounds. Since the dialkylation of malonic ester,[2,3] acetoacetic ester,[4] and ethyl cyanoacetate[4] with 1,4-dihalo-2-butenes has been reported on several occasions, it seemed reasonable that the structurally similar 2-carbethoxycyclohexanone could be used for the preparation of bicyclic compounds.

Dialkylation of malonic ester with 1,4-dihalo-2-butenes has led to two products, 4,4-dicarbethoxycyclopentene and diethyl 2-vinylcyclopropane-1,1′-dicarboxylate,[2,3] depending on whether an allyl shift of the dihalide takes place in the reaction. The cyclopentene derivative is the major product when the *cis* dihalide is used, and the cyclopropane derivative is the major product when the *trans* dihalide is used.[2,3]

It was anticipated, therefore, that dialkylation of 2-carbethoxycyclohexanone with *cis*-1,4-dichloro-2-butene would lead to 1-carbethoxybicyclo[4.3.1]dec-3-en-10-one (Ia), and that the *trans* isomer would give 1-carbethoxy-6-vinylbicyclo[3.2.1]octan-8-one (IIa).



Ia, R = COOEt
b, R = COOH
c, R = H



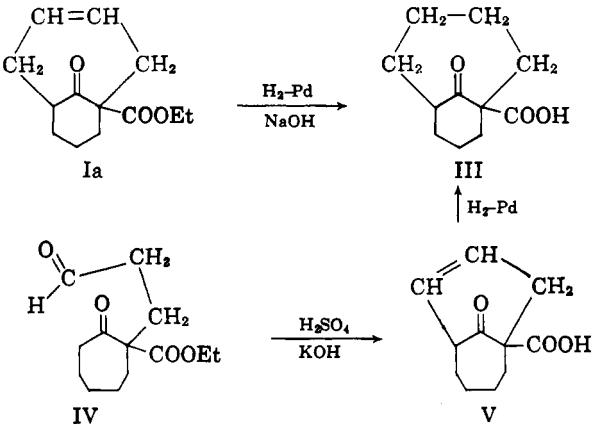
IIa, R = COOEt
b, R = COOH

Furthermore, it was anticipated that a separation of the isomeric products would be possible by virtue of the fact that Ib, the acid obtained from the hydrolysis of Ia, would decarboxylate on heating with quinoline, while IIb, the acid from IIa, would probably not decarboxylate under the same conditions.[5]

It was found, however, that both *cis*- and *trans*-1,4-dichloro-2-butene reacted with 2-carbethoxycyclohexanone to give 1-carbethoxybicyclo[4.3.1]dec-3-en-10-one (Ia) in nearly identical yields. There was no indication of the presence of the isomeric IIa.

The structure was indicated by the infrared and n.m.r. spectra of Ib. Confirmation of the structure, however, was obtained when Ia was converted to 1-carboxybicyclo[4.3.1]decan-10-one (III), and the same acid was obtained by an independent synthesis.

Reduction of Ia, followed by hydrolysis of the resulting saturated ester, gave III. The method Cope and Synerholm used to prepare 1-carboxybicyclo[3.3.1]-nonan-10-one from 2-carbethoxycyclohexanone and acrolein[7] also resulted in the preparation of III, when 2-carbethoxycycloheptanone was used instead of 2-carbethoxycyclohexanone. Since the same product was obtained by the two methods, the structure of III, as well as Ia and Ib, was established.



The acid Ib was decarboxylated by heating with quinoline to give bicyclo[4.3.1]dec-3-en-10-one (Ic), an isomer of the bicyclo[4.3.1]dec-7-en-10-one previously reported.[1]

Experimental[8]

Starting Materials.—2-Carbethoxycyclohexanone (Arapahoe Chemicals, Inc.) was fractionated to give a colorless liquid boiling at 77–80° (3 mm.), $n^{23}D$ 1.4821. *trans*-1,4-Dichloro-2-butene (Eastman Yellow Label) was fractionated to give a colorless liquid boiling at 156°, $n^{22}D$ 1.4873, that was completely free of the *cis* isomer.[9] *cis*-1,4-Dichloro-2-butene was prepared by reaction of *cis*-2-butene-1,4-diol (General Aniline and Film Corp.) with thionyl chloride and pyridine in ether.[2] The fractionated product was a colorless liquid boiling at 59° (30 mm.), $n^{22}D$ 1.4871, that was completely free of the *trans* isomer.[9] Acrolein (Eastman Yellow Label) was fractionated twice and used immediately. 2-Carbethoxycycloheptanone was prepared from diethyl oxalate (Eastman White Label) and cycloheptanone[10] (Aldrich Chemical Co.). A colorless liquid boiling at 95° (4 mm.), $n^{22}D$ 1.4701, was obtained.

1-Carbethoxybicyclo[4.3.1]dec-3-en-10-one (Ia). A.—2-Carbethoxycyclohexanone (85 g., 0.5 mole) was added to a solution of sodium (23 g., 1 g.-atom) in 500 ml. of *t*-amyl alcohol. After 30 min. of heating and stirring, the mixture was cooled to room temperature, and *trans*-1,4-dichloro-2-butene (62.5 g., 0.5 mole) was added over 10 min. The mixture was stirred at room temperature for 2 hr. and then refluxed overnight. Filtration of the salt was followed by distillation of the *t*-amyl alcohol. The residue was treated with water, taken up in ether, and dried over anhydrous magnesium sulfate. Removal of the solvent and distillation gave 22.0 g. of liquid boiling at 140–200° (5 mm.) and 36.0 g. of residue. Redistillation gave 17.0 g. of colorless liquid boiling at 130–40° (5 mm.), $n^{22}D$ 1.4940.[11]

B.—When *cis*-1,4-dichloro-2-butene was used, distillation gave 22.5 g. of liquid boiling at 145–200° (3 mm.) and 36.0 g.

(1) R. D. Sands, *J. Org. Chem.*, **28**, 1710 (1963).
(2) K. C. Murdock and R. B. Angier, *ibid.*, **27**, 2395 (1962).
(3) J. Meinwald, P. Gassman, and J. Crandall, *ibid.*, **27**, 3366 (1962).
(4) R. Kierstead, R. Linstead, and B. Weedon, *J. Chem. Soc.*, 1799 (1953).
(5) This prediction is based on the observation that there seems to be a correlation between the sizes of the rings in β-ketobicyclic acids and their ease of decarboxylation. β-Ketobicyclic compounds with at least one seven-membered ring such as 7-methyl-1-carboxybicyclo[4.3.1]dec-7-en-10-one[6] and 1-carbethoxybicyclo[4.3.1]dec-7-en-10-one[1] are readily decarboxylated. 4-Methyl-1-carboxybicyclo[3.3.1]non-3-en-9-one,[6] 1-carboxybicyclo-[3.3.1]-non-3-en-9-one, and 1-carboxybicyclo[3.3.1]nonan-9-one,[7] all with only six-membered rings, are not decarboxylated by heating with quinoline.
(6) V. Prelog, P. Barman, and M. Zimmerman, *Helv. Chim. Acta*, **32**, 1284 (1949).
(7) A. C. Cope and M. E. Synerholm, *J. Am. Chem. Soc.*, **72**, 5228 (1950).
(8) Microanalyses were by Weiler and Strauss, Oxford.
(9) By chromatographic analysis, using an Aerograph A-700 Autoprep with a 10 ft. × ⅜ in. column packed with 20% Dow-710 on acid-washed, 60–80-mesh Chromosorb W.
(10) H. R. Snyder, L. A. Brooks, and S. H. Shapiro, "Organic Syntheses," Coll. Vol. II, John Wiley and Sons, Inc., New York, N. Y., 1943, p. 531.
(11) Further purification was not attempted because of fear of decarbethoxylation.[5]

of residue. Redistillation gave 19.0 g. of colorless liquid boiling at 140–50° (6 mm.), $n^{22}D$ 1.4978.[11,12]

1-Carboxybicyclo[4.3.1]dec-3-en-10-one (Ib).—1-Carbethoxybicyclo[4.3.1]dec-3-en-10-one (25 g.) was refluxed with 10% hydrochloric acid. The hydrolysis mixture was extracted with ether, and the ether extract was washed with sodium bicarbonate solution. Acidification of the sodium bicarbonate solution gave a solid which was recrystallized from toluene to give 3 g. of a pure white solid melting at 146–147°. The ester from the *cis* and that from the *trans* dichloride both gave the same acid (mixture melting point). The 2,4-dinitrophenylhydrazone had m.p. 236–238°. The n.m.r. spectrum indicated the structure to be Ib, not IIb.[13]

Anal. Calcd. for $C_{11}H_{14}O_3$: C, 68.04; H, 7.21. Found: C, 68.12; H, 7.24.

1-Carboxybicyclo[4.3.1]decan-10-one (III). A.—1-Carbethoxybicyclo[4.3.1]dec-3-en-10-one[14] (15 g.) was dissolved in 160 ml. of 95% ethanol containing 1.4 g. of 5% palladium on barium sulfate (Engelhard Industries, Inc.) and agitated at room temperature in the low-pressure hydrogenator under a hydrogen pressure of 32.5 lb./in.^{2} for 23 hr. Filtration of the catalyst and reduced pressure evaporation of the alcohol gave a residue that was refluxed with a solution of 10 g. of sodium hydroxide in 75 ml. of water for 4 hr. The reaction mixture was treated with decolorizing carbon and filtered. The cooled filtrate was washed with ether and then acidified. The resulting oil was taken up in ether, washed with water, and dried over anhydrous magnesium sulfate. The 9 g. of residue from evaporation of the ether was taken up in a bicarbonate solution which was then washed with ether. Acidification gave an oil which was taken up in ether and dried. The solid obtained by evaporation of the ether was recrystallized from methylcyclohexane to give pure white III, melting at 102–103°. The 2,4-dinitrophenylhydrazone had m.p. 189°.

Anal. Calcd. for $C_{11}H_{16}O_3$: C, 67.35; H, 8.16. Found: C, 67.36; H, 8.29.

B.—2-Carbethoxycycloheptanone (0.15 mole) was treated with acrolein at −70° according to the method of Cope and Synerholm[7] to give 18.3 g. of crude β-(1-carbethoxy-2-ketocycloheptyl)propionaldehyde (IV), boiling at 165–185° (7 mm.), $n^{21}D$ 1.4774. The 18.3 g. of aldehyde gave 3 g. of crude solid (V) after ring closure and hydrolysis. The 2,4-dinitrophenylhydrazone had m.p. 230° dec.

Anal. Calcd. for $C_{17}H_{18}N_4O_6$: C, 54.54; H, 4.81. Found: C, 54.50; H, 4.88.

When the solid was reduced as above and then recrystallized from methylcyclohexane, a pure white solid melting at 102–103° was formed. There was no depression of melting point when mixed with the acid from A.

Bicyclo[4.3.1]dec-3-en-10-one (Ic).—1-Carboxybicyclo[4.3.1]-dec-3-en-10-one (1.25 g.) was refluxed with 10 ml. of quinoline for 1 hr. The mixture was cooled and treated with ether. The ether solution was washed with water, sodium bicarbonate solution, water, dilute hydrochloric acid, and again with water. The ether solution was dried and evaporated to give 1 g. of brown residue. Distillation of 3.6 g. of the residue isolated 1 g. of white solid from the quinoline still present, b.p. 85° (4 mm.), m.p. 72–73°. The 2,4-dinitrophenylhydrazone had m.p. 175–176°.

Anal. Calcd. for $C_{16}H_{18}N_4O_4$: C, 58.18; H, 5.45. Found: C, 58.11; H, 5.48.

(12) There were differences in the boiling points and refractive indices of the distillates from the *cis* and *trans* dihalides only because the distillates contained all the same impurities (alcohol, cyclohexanone, 3,4-dichloro-1-butene, *cis*- and *trans*-1,4-dichloro-2-butene, and carbethoxycyclohexanone) in slightly varying amounts.

(13) Carried out and interpreted by Varian Associates, Palo Alto, Calif.

(14) The ester prepared from *trans*-1,4-dichloro-2-butene was used.

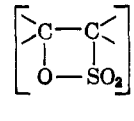
The Reaction of Carbyl Sulfate with Pyridine

DONALD L. KLASS

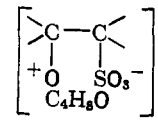
Research Center, The Pure Oil Company, Crystal Lake, Illinois

Received February 21, 1964

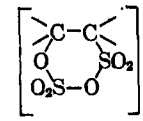
Bordwell and co-workers studied the mechanism of sulfonation of olefins and concluded that β-sultones (I), or their dioxane-solvated oxonium ions (II), and cyclic sulfonate–sulfates (III) are important intermediates when 1 mole of olefin is treated with 1 or 2 moles of sulfur trioxide–dioxane, respectively.[1] The existence of these intermediates, which were isolated in some instances,[2] was supported, for example, by the formation of 2-(1-proto-1-pyridyl)-1-hexanesulfonate[3a] on sequential treatment of 1-hexene with 1 mole of sulfur trioxide–dioxane and excess pyridine, and by the formation of the aniline salt of 2-hydrosulfato-1-hexanesulfonanilide on sequential treatment of 1-hexene with 2 moles of sulfur trioxide–dioxane and aniline.[3b] The reaction of intermediates of type III with tertiary amines was not reported.



I

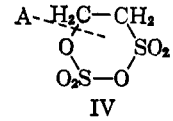


II



III

The purpose of our investigation was to conduct a limited study of the reactivity of pure carbyl sulfate (IV) with pyridine. We expected that, if reaction occurred, the most probable reaction would be C–O cleavage at bond A with resultant formation of a betaine salt.[4] Such a reaction would suggest that the



IV

structures of the products formed on sequential treatment of olefins with sulfur trioxide and amines may not clearly differentiate between reaction paths which involve intermediates of structures I, II, and III.

The reaction of IV and pyridine was carried out in ethylene chloride solvent so that the reactive species was IV and not a decomposition product.[5] At room temperature, IV reacted rapidly with pyridine to afford an oily precipitate which gave a crystalline solid in relatively good yield on crystallization from N,N-dimethylformamide. The crystalline product was characterized as the betaine salt, 2-(1-proto-1-pyridyl)-1-ethanesulfonate (V),[3a] by elemental, infrared, and p.m.r. analyses, and by examination of its chemical properties. The product had a high melting point and was soluble in polar solvents. Aqueous solutions of the product were neutral, gave negative tests for

(1) For a summary of the literature on the mechanism of reaction of sulfur trioxide with olefins, see E. E. Gilbert, *Chem. Rev.*, **62**, 549 (1962).

(2) See ref. 1, p. 564.

(3) (a) This nomenclature has been used previously by Professor Bordwell and co-workers. See, for example, F. G. Bordwell, M. L. Peterson, and C. S. Rondestvedt, Jr., *J. Am. Chem. Soc.*, **76**, 3945 (1954). Reference 7 of this paper is reproduced here: "This nomenclature has been suggested by Dr. F. Y. Wiselogle to fill the need for a suitable prefix to designate a substituent which bears a positive charge. "Proto" signifies the addition of a proton; $C_5H_5N^+H$ is then protopyridine and $C_5H_5N^+-$ is the 1-proto-1-pyridyl group. According to this nomenclature a dipolar ion, such as sulfanilic acid, can be given the systematic name *p*-protoaminobenzenesulfonate, rather than *p*-aminobenzenesulfonic acid, which misrepresents the structure." (b) F. G. Bordwell and M. L. Peterson, *ibid.*, **76**, 3952 (1954).

(4) Betaine-type compounds are defined in this paper as internal salts containing the anion of the sulfonic acid group and a quaternary fully alkylated nitrogen atom.

(5) Infrared analyses of ethylene chloride solutions of IV indicated that decomposition is nil when IV is carefully dissolved in the solvent. Ethylene chloride is a suitable recrystallization solvent for IV.