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Highly Branched Molecules. III. The Preparation of Tri-*t*-butylcarbinol by Means of *t*-Butyllithium

BY PAUL D. BARTLETT AND EDWIN B. LEFFERTS

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Tri-*t*-butylcarbinol is available in 81% yield by the addition of *t*-butyllithium to hexamethylacetone in ether at -60 to -70° . The alcohol has a molal freezing point depression constant of 74° . It yields a *p*-nitrobenzoate, m.p. 105 – 106° , which reacts with first-order kinetics in part aqueous solvents, the rate being increased by acids and quite insensitive to bases.

When *t*-butyllithium was first prepared¹ it was found to yield only reduction product on reaction with hexamethylacetone. The preparation of tri-*t*-butylcarbinol using *t*-butyl chloride and sodium² has been successfully repeated³ but the yields were always poor. We have found that the handling of *t*-butyllithium at temperatures below -40° not only makes possible the preparation of this organometallic compound in ether with reliably high yields⁴ but also makes tri-*t*-butylcarbinol available in good yield by the addition of *t*-butyllithium to hexamethylacetone. *t*-Butyllithium in ether solution was prepared in 75% yield as determined by titration. When the calculated amount of di-*t*-butyl ketone was added to this solution, tri-*t*-butylcarbinol was obtained, melting from 113 – 117° , in a yield of 81%. Further recrystallization raised the melting point to 117.5° . The molal freezing point depression constant was found to be 74° by the method of Rast modified by Muenster,⁵ using naphthalene and cholesterol as solutes.

Attempts to prepare the *p*-toluenesulfonate of tri-*t*-butylcarbinol were unsuccessful, but the *p*-nitrobenzoate could be had from the reaction of the acid chloride with the lithium derivative of tri-*t*-butylcarbinol. The ester melted at 105 – 106° . Neither ketene nor phenyl isocyanate could be induced to react with the carbinol.

Because tri-*t*-butylcarbinol yields a mixture of chlorides whose structures are not known,³ it was desirable to find derivatives of highly-branched alcohols of this type whose structure could be established and which would also yield solvolytic reactions. Such proved to be the case with the *p*-nitrobenzoate of tri-*t*-butylcarbinol. The solvolysis of this ester was followed kinetically in two solvents for which comparative data were available in the case of ethyl *p*-nitrobenzoate, namely, 60% acetone–water and 75% methanol–water. The solvolysis of *t*-butyl *p*-nitrobenzoate also was studied for comparison, and the contributions of acid and basic catalysis to this reaction and to the solvolysis of the tri-*t*-butylcarbinyl ester were evaluated. In contrast to the ethyl and *t*-butyl esters the *p*-nitrobenzoate of tri-*t*-butylcarbinol has a readily measurable, uncatalyzed solvolysis rate constant amount-

ing at 25° to 4.8×10^{-5} sec.⁻¹ in 75% methanol and 1.50×10^{-5} sec.⁻¹ in 60% acetone. The bimolecular rate constant for base-catalyzed hydrolysis for the three esters in 60% acetone is 260, 1.7 and 1.1 l./mole sec., respectively. In 75% methanol the constants for the ethyl and *t*-butyl esters are 30 and 0.9, respectively, and that for the highly branched ester is so small as not to be surely detectable in the presence of the water reaction. In 75% methanol an acid catalysis appears with rate constants of 2×10^{-6} , about 10^{-7} , and 4.9×10^{-3} l./mole sec., respectively.⁶

With the ready availability of tri-*t*-butylcarbinol and the occurrence of solvolysis at a measurable rate in its *p*-nitrobenzoate, the way is open for the correlation of rate with structure in a series of highly branched esters of known structures. Such a correlation will be reported in Part IV of this series.⁷

Although our survey of the hydrolysis rates has been of a preliminary nature without control of pH or salt concentration, a striking difference in the behavior of the highly branched and less branched *p*-nitrobenzoates is indicated. Ethyl *p*-nitrobenzoate is strongly subject to hydrolysis by hydroxide ion in 75% methanol while its rate of acid hydrolysis is less than one-thousandth as great. *t*-Butyl *p*-nitrobenzoate is still subject to normal ester hydrolysis, but here branching in the alcohol has diminished the rate of both acid and basic hydrolysis, the latter slightly more than the former. Neither of these esters shows a hydrolysis ascribable to the action of pure water. The *p*-nitrobenzoate of tri-*t*-butylcarbinol is so highly hindered that it is not surprising to find basic catalysis of its hydrolysis immeasurably small. At the same time there is a water reaction due to the operation of the SN1 mechanism which causes this ester to hydrolyze faster in pure water than *t*-butyl *p*-nitrobenzoate does in 0.04 *M* alkali. Entirely contrary to the trend of the series, but in accord with expectations from the SN1 mechanism, the *p*-nitrobenzoate of tri-*t*-butylcarbinol shows a pronounced acid-catalyzed hydrolysis. This can scarcely be due to attack on the carbonyl group which is already negligibly slow in such solutions of the ethyl and *t*-butyl esters. It is entirely reasonable, however, that this highly branched ester when protonated at the carbon

(1) P. D. Bartlett, C. G. Swain and R. B. Woodward, *THIS JOURNAL*, **63**, 3229 (1941).

(2) P. D. Bartlett and A. Schneider, *ibid.*, **67**, 141 (1945).

(3) M. Swain, Thesis, Radcliffe College, 1949; Part II of this series, *ibid.*, **77**, 2801 (1955).

(4) P. D. Bartlett, S. Friedman and M. Stiles, *ibid.*, **75**, 1771 (1953).

(5) I. Gattermann and H. Wieland, "The Practical Methods of Organic Chemistry," The Macmillan Co., New York, N. Y., 1943, p. 86.

(6) E. Tommila, *et al.*, *Suomen Kemistilehti*, **18B**, 24 (1945); *C. A.*, **40**, 6956^g (1946); *Ann. Acad. Sci. Fennicae, Ser. A-II*, Chem. no. **16**, 14 (1945); *C. A.*, **41**, 903^d (1947); *Suomen Kemistilehti*, **17A**, 1 (1944); *C. A.*, **40**, 4590^g (1946); *Ann. Acad. Sci. Fennicae, Ser. A 59*, no. **3**, 3 (1942); *C. A.*, **38**, 6172^g (1944); *Ann. Acad. Sci. Fennicae, Ser. A 57*, no. **13**, 3 (1941); *C. A.*, **38**, 6171^g ff. (1946); *J. Chem. Soc.*, 1801 (1938); E. W. Timm and C. N. Hinshelwood, *ibid.*, 862 (1938); R. A. Harman, *Trans. Faraday Soc.*, **35**, 1336 (1939).

(7) P. D. Bartlett and M. Stiles, *THIS JOURNAL*, **77**, 2806 (1955).

group should undergo ionic fission more rapidly than when neutral and uncombined.

Experimental

t-Butyllithium was prepared readily in 75% yield as follows: Finely divided lithium was prepared by melting lithium in mineral oil previously dried with sodium, adding a few drops of oleic acid to prevent coalescence, and shaking vigorously for a few seconds. The mixture was cooled and filtered through a thin pad of glass wool, the lithium was washed with ether and transferred to the reaction flask. Up to this point no effort to maintain an inert atmosphere was necessary. The particles of lithium were light silvery gray in color and about one mm. in diameter.

The one-liter, 3-neck reaction flask had ground glass joints generously lubricated, sealed stirrer, addition funnel adapted to pass nitrogen into the flask, and an outlet tube leading to a bubbler with mineral oil in it. The purpose of the bubbler was to provide an indication of the pressure of nitrogen and any evolution of gas. The stirrer was a tantalum wire Hershberg⁸ type which gave efficient whipping of the solution. Good stirring was most important as the particles of lithium tended to become covered with salt and sink to the bottom without further reaction. The outlet tube carried a low-temperature thermometer whose bulb extended into the flask. The flask was arranged for cooling with a Dry Ice-acetone mixture. Ether was measured into the flask to bring the volume to about 300–400 ml. and the flask was cooled to –35 to –40°. A solution of *t*-butyl chloride in an equal volume of ether at room temperature was added dropwise, not allowing the temperature to rise above –30°. The reaction proceeded smoothly and the addition required about 2–3 hours for a one-mole run. If the temperature rose much above –30° a rapid evolution of unsaturated gas occurred and strong cooling was required to control the reaction. At –70° the reaction was very slow. A sample was withdrawn and run into water and titrated with standard acid. The yield was 75% shortly after the end of the addition. Stirring for several more hours did not improve the titration. Gilman's color test⁹ showed an intense blue in the Michler ketone solution, but no color after hydrolysis and treatment with iodine in acetic acid.

Tri-*t*-butylcarbinol was prepared by adding a solution of hexamethylacetone (equivalent to the *t*-butyllithium) in ether to a solution of the lithium compound prepared as above and subsequently cooled to –60 to –70°. The addition lasted two hours and the mixture was stirred an additional hour. The tip of the addition funnel was scraped clean of lithium particles and 500 ml. of water was added to hydrolyze the adduct. The cooling bath was removed and the mixture allowed to rise to room temperature during the hydrolysis. From 11.7 g. of lithium, 80 g. of *t*-butyl chloride and 80 g. of hexamethylacetone was obtained 93 g. of tri-*t*-butylcarbinol, a yield of 81%. The product melted at 113–117° after one precipitation by pouring an ethanol solution into an equal volume of cold water.

(8) L. Fieser, "Experiments in Organic Chemistry," D. C. Heath and Co., Boston, Mass., 1941.

(9) H. Gilman and F. Schulze, *THIS JOURNAL*, **47**, 2002 (1925).

Tri-*t*-butylcarbonyl *p*-Nitrobenzoate.—The lithium salt of tri-*t*-butylcarbinol obtained by the *t*-butyllithium synthesis with hexamethylacetone was added to a solution of *p*-nitrobenzoyl chloride in ether at 0° with stirring. From an aliquot containing approximately 0.15 mole of lithium salt and 0.2 mole of *p*-nitrobenzoyl chloride in ether was obtained 25 g. (50%) of ester. After distillation of the ether and some hexamethylacetone under vacuum, the residue was taken up in petroleum ether and recrystallized. The crystals were slow to form and better results were obtained by dissolving the ester in acetone and precipitating with water. Some solvolysis took place, but the main contaminant, *p*-nitrobenzoic acid, remained in solution. When hot methanol was used only *p*-nitrobenzoic acid was obtained as crystals. The mother liquor yielded small amounts of ester, acid and tri-*t*-butylcarbinol but not an amount equivalent to the decomposed ester.

Tri-*t*-butylcarbonyl *p*-nitrobenzoate, m.p. 105–106° (needles out of acetone–water) decomposes at about 115° and remelts around 200° (m.p. *p*-nitrobenzoic acid 240°). With slower heating the decomposition point is lowered and the remelting point raised (see Part IV).

Anal. Calcd. for C₂₀H₃₁O₄N: C, 68.75; H, 8.95; N, 4.01. Found: C, 67.13; H, 9.22; N, 3.98.

Molal Freezing Point Depression Constant.—The method of Rast, modified by Muenster, as described in Gattermann and Wieland⁶ was used. Thin-walled Pyrex melting-point tubes were drawn 3 mm. in diameter and 5 cm. long. The tri-*t*-butylcarbinol and other substance were weighed directly into the tubes which were then sealed off. The mixture was melted and thoroughly mixed and then the solidification temperature was determined using Anschütz thermometers reading to the nearest tenth of a degree.

	<i>T</i> , °C.	Molal f.p. const., °C.
Pure tri- <i>t</i> -butylcarbinol	117.5	
+9.2 mg. naphthalene in 102.6 mg.	65.5	74.0
+9.5 mg. cholesterol in 78.8 mg.	94.5	73.5

The Measurement of the Hydrolysis Rates.—The solvents used were those of Tommila⁶ so that comparison could be made with his results. The 60% acetone (56% by weight) was made up by diluting 40 ml. of water to 100 ml. with reagent grade acetone; this required 64.5 ml. of acetone. The 75% methanol was made up by diluting 25 ml. of water to 100 ml. with absolute methanol; this required 78 ml. and the mixture was 72.2% methanol by weight. Standardized 0.1 *N* solutions of sodium hydroxide were made in each solvent and aliquot portions pipetted as needed. The solution in acetone became brown after a few days and had to be made up again, although the titer did not change. The acid catalyst was 0.1 *N* benzenesulfonic acid in the methanol–water solvent. All solutions were kept in the 25.0° thermostat.

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CAMBRIDGE, MASS.