alkoxide ion pair. The preponderance of the less stable alcohol isomer can reasonably be attributed then to the steric requirements of the lithium ion and its solvation shell. In the same way, protonation of the hydroxyl group, the first step of the dehydration reaction, must in **2a** be hindered by the proximity of the *o*-methyl to such an extent that this step has a very small equilibrium constant or may even be rate determining.[8] This feature is absent in **3a** whose reactivity may be further enhanced by relief of steric strain between the *o*-methyl and *tert*-butyl groups in the normally rate-determining heterolytic bond cleavage step.[9]

Rate constants for the conversion of **3a** into **2a** in dodecane indicate that the activation enthalpy is 25.9 kcal/mol, that is, over 11 kcal/mol greater than that for rotation about the phenyl to sp^3 carbon bond of **1** in nonane.[2] This value is unusually high for rotation involving an sp^3 carbon; to date comparable values have only been reported for 9-arylfluorenes[10] and triarylmethanes.[11]

Experimental Section

Gas Chromatography. GLC was performed on a 25-cm column of 10% SE-30 on Chromosorb 80/100 at 120 °C with an inlet pressure of 1 atm. By this means the extent of **3a** → **2a** isomerization is limited to 5%; the data have been corrected appropriately.

Synthesis of *o*-Tolyldi-*tert*-butylcarbinol. Di-*tert*-butyl ketone was added to an equimolar quantity of *o*-tolyllithium in ether at ambient temperature (20 °C) under argon. After 1 h the reaction mixture was poured onto ice, washed with water, and dried over Na_2SO_4 before evaporation of the solvent at reduced pressure. GLC analysis of the crude reaction product revealed two compounds, **2a** and **3a**, in the ratio 14:86 and having retention times of 90 and 120 s, respectively. Distillation of this mixture gave **2a** in good yield [69%, bp 116 °C (2mm), mp 35 °C]. The unstable isomer **3a** was readily separated from the **2a**–**3a** mixture by chromatography on a column of alumina (Brockmann activity II–III) in pentane.

Alcohol **2a** has ir (CCl_4) 3644 cm^{-1} (free hydroxyl); NMR (Me_2SO) singlet (δ 1.11), 18 H of *tert*-butyl; singlet (δ 3.84), 1 H of hydroxyl; singlet (δ 2.60), 3 H of methyl; multiplet (δ 6.95), 3 aromatic H; multiplet (δ 7.42), 1 aromatic H.

Anal. Calcd for $C_{16}H_{26}O$: C, 81.99; H, 11.18. Found: C, 81.78; H, 10.96.

Alcohol **3a** was obtained as a slightly impure oil with ir (CCl_4) 3613 and 3650 cm^{-1} (π-bonded[12] and free hydroxyl); NMR (Me_2SO) singlet (δ 1.13), 18 H of *tert*-butyl; singlet (δ 4.35), 1 H of hydroxyl; singlet (δ 2.62), 3 H of methyl; multiplet (δ 7.00), 3 aromatic H; multiplet (δ 8.01), 1 aromatic H.

Synthesis of *p*-Methoxy-*o*-tolyldi-*tert*-butylcarbinol. Addition of the aryllithium to di-*tert*-butyl ketone gave, after the usual workup, a product mixture which yielded pure **2b** upon standing for 4–5 weeks (4%, mp 96 °C). No attempt was made to isolate **3b.**

Anal. Calcd for $C_{17}H_{28}O_2$: C, 77.22; H, 10.67. Found: C, 77.01; H, 10.63.

Alcohol **2b** has ir (CCl_4) 3643 cm^{-1} (free hydroxyl); NMR (Me_2SO) singlet (δ 1.09), 18 H of *tert*-butyl; singlet (δ 2.61), 3 H of methyl; singlet (δ 3.72), 3 H of methoxyl; singlet (δ 3.78), 1 H of hydroxyl; multiplet (δ 6.53), 2 aromatic H; multiplet (δ 7.38), 1 aromatic H.

Isomerization Kinetics. A thermostated solution of **3a** (0.02 M) and an internal standard, octadecane (0.01 M) in dodecane was sampled at convenient intervals and the reaction mixture analyzed by GLC as described above. First-order rate constants (±1–5%) were determined from the relative peak areas of **3a** and octadecane: 80 °C, 1.26×10^{-5}; 95 °C, 5.64×10^{-5}; 112 °C, 2.75×10^{-4}; 130 °C, 1.26×10^{-3} s^{-1}, whence $\Delta H^{\ddagger} = 25.9 \pm 0.4$ kcal/mol and $\Delta S^{\ddagger} = -8.2 \pm 0.9$ eu.

Dehydration Kinetics. Owing to the low solubility of octadecane a modification of the above method was employed. Samples (200 μl) of a solution of the alcohol (0.02 M) in H_2SO_4–acetic acid at 25 °C were quenched in 20% Na_2CO_3 solution (5 ml). After addition of 20 μl of a 0.1 M solution of octadecane in benzene the mixture was extracted with pentane (500 μl). Dehydration rates constants were as follows: **2a** (10% v/v H_2SO_4 in anhydrous acetic acid), 1.53×10^{-5}; **2b** (10% H_2SO_4), 3.02×10^{-4}; **3a** (2% H_2SO_4), 2.74×10^{-3} s^{-1}. For comparison *p*-tolyldi-*tert*-butylcarbinol has rate constants of 4.24×10^{-3} and 6.31×10^{-5} s^{-1} in 10% and 2% H_2SO_4, respectively. We estimate then that the **3a**:**2a** rate ratio is at least 10^4.

Registry No.—**2a,** 59434-44-5; **2b,** 59434-45-6; di-*tert*-butyl ketone, 815-24-7; *o*-tolyllithium, 6699-93-0.

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(3) J. E. Dubois and J. S. Lomas, *Tetrahedron Lett.,* 1791 (1973), and references cited therein.

(4) E. L. Eliel, N. L. Allinger, S. J. Angyal, and G. A. Morrison, "Conformational Analysis", Wiley, New York, N.Y., 1965, p 12.

(5) The **2b:2a** rate ratio in 10% v/v H_2SO_4–HOAc is 20, closely similar to that (13.3) of the corresponding phenyl derivatives.[6]

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(8) In a previous note[3] we suggested that steric inhibition to solvation of the intermediate carbonium ion was responsible for the low reactivity of some hindered alkyldi-*tert*-butylcarbinols.

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(11) A rather complicated situation arises in triarylmethanes with three different aryl groups. Mislow et al. have isolated diastereomers which interconvert via a one-ring flip mechanism, the isomerization barrier ($\Delta G^{\ddagger}$) being about 30.5 kcal/mol: P. Finocchiaro, D. Gust, and K. Mislow, *J. Am. Chem. Soc.,* **96,** 3198 (1974).

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A Convenient Two-Step Synthesis of 2,6-Di-*tert*-butyl-4-methylpyridine, a Sterically Hindered Nonnucleophilic Base

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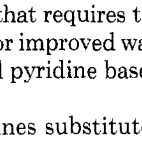
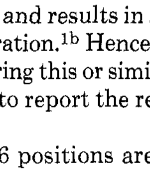
It is well known that pyridine rings containing the 2,6-di-*tert*-butyl functionality enable such bases to distinguish between Bronsted (protonic) and Lewis acids owing to steric crowding in the region of the nitrogen atom.[1a] In connection with some aspects of our work on vinyl triflate chemistry we had need of relatively large amounts of such a nonnucleophilic base. However, the usual synthesis of 2,6-di-*tert*-butylpyridine (**1**) from pyridine and *tert*-butyllithium requires anhydrous conditions, gives low yields, and results in a mixture of isomers that requires tedious separation.[1b] Hence, we decided to look for improved ways of preparing this or similar sterically hindered pyridine bases and wish to report the results in this note.

Pyridines substituted in the 2,6 positions are easily synthesized from the corresponding pyrylium salts[2] in nearly quantitative yields, i.e., conversion of **3** should yield **1.** Although pyrylium salt **3** is difficult to obtain, pyrylium salts substituted with an additional methyl group in the 4 position, **4,** are readily available in a single step. Compound **4** may then



1, R = H
2, R = CH_3

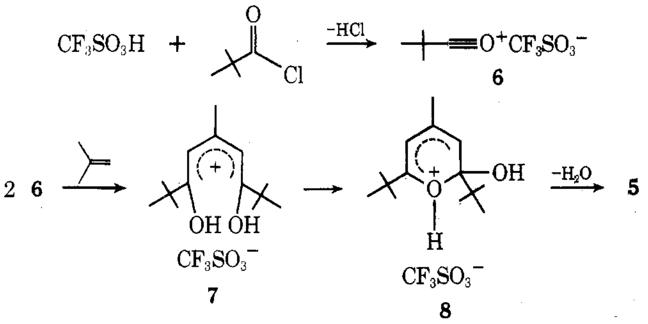


3, R = H
4, R = CH_3
5, R = CH_3; X = OTf

be converted into the title compound, **2.** Compound 4 has been prepared previously in yields of 4–40% starting with the chloride or anhydride of pivalic acid and employing various counterions such as ClO_4^-, $FeCl_4^-$, or $AlCl_4^-$.[3]

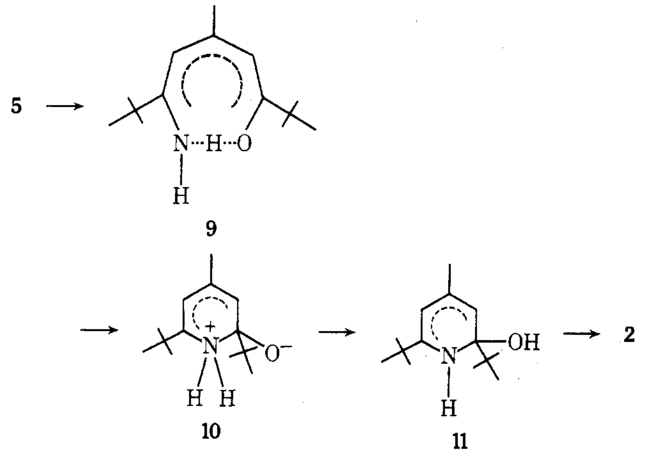
We have found that use of pivaloyl chloride and trifluoromethanesulfonic (triflic, -OTf) acid greatly simplifies the procedure for the preparation of **5** and results in improved yields of 54–60%. We assume that the reaction proceeds according to Scheme I;[4] the acylonium triflate, **6,** formed[5] from pivaloyl chloride and triflic acid adds twice to isobutylene, generated in situ from *tert*-butyl alcohol, to form **7,** which cyclizes to **8** and upon loss of water gives **5.** The reaction proceeds poorly unless the mixture is heated to 85 °C. Use of more than 1 mol of *tert*-butyl alcohol or less than 2 mol of triflic acid results in a lower yield. Use of anhydrous *p*-toluenesulfonic acid, polyphosphoric acid, sulfuric acid, or P_4O_{10} as a catalyst and counterion instead of triflic acid fails. Pyrylium salt **5** is nonhygroscopic and stable indefinitely at room temperature.

Scheme I



Crude **5** is readily converted into **2** by treatment with ethanolic ammonium hydroxide for 2 h at −40 °C. The reaction can be monitored by the formation and disappearance of a brilliant yellow intermediate[6] which is likely to be intramolecularly hydrogen bonded **9**[7] in Scheme II.

Scheme II



Upon subsequent reaction **9** is required to pass through a sterically crowded zwitterionic cyclic intermediate **10** which should transfer a proton to form **11** and by loss of water relieve crowding and aromatize to **2.** The final product, **2,** is isolated as a colorless, odorless, crystalline solid in 95% yield (55% overall) by extraction with pentane and is purified[8] by column chromatography on activated alumina.

Experimental Section

General. Melting points and boiling points are uncorrected. NMR spectra were recorded on a Varian 360A spectrometer and data are given in δ (ppm) relative to internal Me_4Si; ir spectra were recorded on a Beckman IR5A and are reported in wavenumbers (cm^{-1}) calibrated to the 1603-cm^{-1} line of polystyrene. Pentane (Phillips), pivaloyl chloride (Aldrich), trifluoromethanesulfonic acid (3M), and *tert*-butyl alcohol (Baker) were used directly without purification, as were reagent grade inorganic chemicals. Alumina (Fisher, neutral, 80–200 mesh) was activated by heating in an oven at 200 °C for 24 h.

2,6-Di-*tert*-butyl-4-methylpyrylium Triflate (5). Into a 100-ml three-necked round-bottom flask, equipped with a dry ice condenser capped with a drying tube, nitrogen inlet, constant-pressure addition funnel, and a magnetic stirrer was added 24.2 g (0.2 mol) of pivaloyl chloride and 3.7 g (0.05 mol) of *tert*-butyl alcohol. After the apparatus was flushed with a slow stream of nitrogen, the dry ice condenser was charged with dry ice/isopropyl alcohol and the reaction mixture was heated to 85 °C by means of an oil bath; then 15 g (0.1 mol)[9] of triflic acid was added over a period of 15 min. After addition was completed the mixture was stirred for an additional 10 min at 85 °C; the light brown reaction mixture was then cooled in an ice bath and poured into 100 ml of cold ether. The light tan precipitate was collected by filtration and air dried to give 9.6 g (54%) of pyrylium salt that was used without further purification in the next step. A sample twice recrystallized from $CHCl_3/CCl_4$ (3:1) gives colorless needles: mp 168–169 °C; NMR (CCl_4) δ 1.17 (s, 18 H), 2.07 (s, 3 H), 6.66 (s, 2 H); ir (KBr pellet) 3030, 2965, 1631, 1530, 1494, 1460, 1372, 1266, 1226, 1200, 1144, 1032, 973, 944, 921, 889, 776, 752, and 637 cm^{-1}.

2,6-Di-*tert*-butyl-4-methylpyridine (2). To a 1-l. round-bottom flask containing 100 ml of concentrated ammonium hydroxide cooled to −60 °C was added in one portion with stirring a slurry of 10 g (0.028 mol) of crude pyrylium salt **5** in 200 ml of 95% ethanol also cooled to −60 °C. The yellow reaction mixture was held at −60 °C for 30 min, then maintained at −40 °C for 2 h, during which time the slurry dissolved; the reaction mixture was then allowed to slowly warm up to room temperature. The reaction mixture was poured into 500 ml of a 2% NaOH solution and the resulting emulsion was extracted with four 100-ml portions of pentane; the combined extracts were washed with 25 ml of saturated NaCl and the pentane was removed on a rotary evaporator. The residual light yellow oil was chromatographed on a 50 × 0.5 cm activated alumina column using pentane as the eluent. All of the pyridine was obtained in the first 200 ml of eluent.[10] The pentane was removed on a rotary evaporator to yield 5.46 g (95%) of a colorless oil which solidifies on cooling or standing. Compound **2** sublimes slowly at room temperature and atmospheric pressure forming very thin 5 cm long needles: mp 31–32 °C; bp 148–153 °C (95 mm) [lit.[3a] 223 °C (760 mm)]; chloroplatinate salt mp 213–214 °C dec (lit.[3a] 212 °C); ir (melt) 3000, 1602, 1565, 1480, 1452, 1409, 1356, 1250, 1205, 1162, 1036, 925, 902, 851, and 769 cm^{-1}; NMR (CCl_4) δ 1.75 (s, 18 H), 2.72 (s, 3 H), 7.33 (s, 2 H).

Acknowledgments. This investigation was supported by Public Health Service Research Grant 1-RO-1CA16903-01 from the National Cancer Institute.

Registry No.—**2,** 38222-83-2; **5,** 59643-43-5; pivaloyl chloride, 3282-30-2; *tert*-butyl alcohol, 75-65-0; triflic acid, 1493-13-6.

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(4) A. T. Balaban, W. Schroth, and G. Fischer, *Adv. Heterocycl. Chem.*, **10**, 241 (1969).

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(7) However, other open-chain fully conjugated structures which could give rise to the yellow-colored intermediate might also be possible.

(8) Small amounts of dull-yellow impurities are formed during the conversion of **5** to **2** which cannot be prevented by use of anhydrous NH_3 in EtOH, buffered ammonia solutions, various ammonium salts, $(NH_4)_2SO_4$, NH_4Cl, NH_4OAc, $(NH_4)_2CO_3$, or by different solvents such as *i*-PrOH, CH_3CO_2H, $CHCl_3$, Me_2SO, DMF, CCl_4, and glyme, nor can they be completely removed by distillation, acid–base extraction or activated charcoal; however, column chromatography is successful.

(9) If desired, the excess triflic acid can be recovered as the solid monohydrate by pouring the ether solution remaining after the pyrylium salt is filtered

off into 50 ml of distilled water, separation of the two phases, extraction with 10 ml of pentane to remove pyvalic acid, and evaporation of the aqueous layer to dryness.

(10) The progress of the elution can be monitored by occasionally spotting a fluorescent TLC plate and examining the plate under short-wave uv light; the pyridine appears as a dark blue spot.

Carbon-13 Nuclear Magnetic Resonance Examination of Some [1-^{2}H]-4-*tert*-Butylcyclohexyl Derivatives

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Recently in this journal, one of us reported[2] the preparation of *cis*- and *trans*-4-*tert*-butylcyclohexane-*1*-d_1, and their characterization by infrared and ^{2}H nuclear magnetic resonance spectroscopy. These compounds, and their 1-oxy precursors, appeared attractive subjects for ^{13}C NMR examination, as considerable insight into the effects of ^{2}H substitution on ^{13}C spectra in a geometrically well-defined cycloalkyl system would result, and complement information available for other ^{2}H-substituted systems.[3-8] In addition, the 4-alkylcyclohexyl system frequently is employed in stereochemical and mechanistic studies, and with the growing use of ^{13}C NMR in this area, it is important to provide parameters for this system.

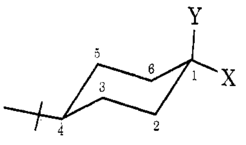
***trans*-4-*tert*-Butylcyclohexyl mesylate** provides a well-separated spectrum which is relatively straightforward to assign. C_1, bearing the mesyl ($-OSO_2CH_3$) function, resonates at lowest field (82.16 ppm) and C_4, $(CH_3)_3C$, and $(CH_3)_3C$ are assigned on the bases of chemical shifts and intensities. Differentiation between $C_{2,6}$ and $C_{3,5}$ is based on the expected greater shielding of $C_{3,5}$, as these carbons are located γ and anti-periplanar to the oxy function.[9] Examination of the spectrum of the 1-^{2}H isomer of this (trans) mesylate confirms the assignment of C_1 (signal now not visible under our pulse conditions) and of $C_{2,6}$ which has experienced a two-bond upfield (i.e., negative) ^{2}H isotope effect of −0.13 ppm, while the signal assigned to $C_{3,5}$ is unaffected within experimental error. This is consistent with other observations that three-bond ^{2}H isotope effects on chemical shifts are quite small.[3,4] We also anticipated that the $C_{3,5}$ signal should be perceptibly broader than that of $C_{2,6}$, because of the operation of significant vicinal ^{2}H–^{13}C coupling.[5,6] The signal of $C_{3,5}$ appears marginally broader, but a strong effect would not be expected for a dihedral angle of 60° (vide infra).

The spectrum of *trans*-4-*tert*-butylcyclohexyl tosylate is similar in many respects to that of the mesylate, and assigned with the same criteria. Another measure of the two-bond isotope effect (at $C_{2,6}$) is provided (−0.11 ppm).

***trans*- and *cis*-4-*tert*-Butylcyclohexane-*1*-d_1.** The spectrum of *tert*-butylcyclohexane was reported previously by Roberts,[10] but at the frequency employed several signals were not well separated, and assignments could not be definite. The cis isomer (i.e. axial ^{2}H) was examined initially as mass spectral examination showed it to be ~90% ^{2}H enriched, and hence the regular *tert*-butylcyclohexane (~10%) would serve as a useful internal standard for isotope shifts. One and two-bond isotope effects of −0.43 and −0.09 ppm (i.e., at C_1 and $C_{2,6}$, respectively) are measured, while any three-bond isotope effect must be less than 0.05 ppm.

The spectra of the above compounds are reproduced in Figure 1, and using the *tert*-butyl resonance as standard, it is clear that there are significant differences in the one- and two-bond isotope effects. This is not surprising as differences in other spectroscopic properties of equatorial and axial ^{2}H are well established.[11] The difference appears greater for the two-bond isotope effect.

Table I. Carbon-13 NMR Parameters[a] for 4-*tert*-Butylcyclohexyl Systems

	Compd 	Carbon						
Registry no.		1	2,6	3,5	4	$(CH_3)_3C$	$(CH_3)_3C$	Others
	X = Y = H	26.61	27.09	27.44	48.01	27.30	32.26	
	(reported[10])	27.2	27.8	28.2	48.9	27.7	32.7	
53042-76-5	X = H; Y = D[b,c]	26.18	27.00	27.44	48.01	27.30	32.26	
		(−0.43)	(−0.09)	~0[e]				
17553-36-5	X = D; Y = H	26.16	26.93	27.32	47.94	27.27	32.24	
	[corrected against							
	$(CH_3)_3C$ as standard][b]	26.19	26.96	27.35	47.97	27.30	32.27	
		(−0.42)	(−0.13)	(−0.09)				
18508-90-2	Y = H; X = OSO_2CH_3	82.16	33.31	26.65	46.74	27.57	32.25	38.81
53111-68-5	Y = D; X = OSO_2CH_3[b]	n.o.	33.18	25.62	46.72	27.57	32.26	38.81
		d	(−0.13)	(~0)[e]				
7453-05-6	Y = H; X = $OSO_2C_6H_4CH_3$	81.78	32.58	25.30	46.12	27.24	31.88	21.39; 126.30; 128.44 133.53; 142.86
53042-75-4	Y = D; X = $OSO_2C_6H_4CH_3$[b]	n.o.	32.47	25.33	46.12	27.24	31.91	21.41; 126.33; 128.41 133.59; 142.86
		d	(−0.11)	(~0)[e]				

[a] Spectra recorded at 22.625 or 67.89 MHz (Bruker). Chemical shifts for dilute $CDCl_3$ solutions referenced to internal Me_4Si. [b] Values in parentheses are isotope shifts in parts per million. [c] $J_{^{13}C-^{2}H}$ = 19.2 Hz. [d] Signal not observable under our pulse conditions. [e] Not greater than experimental error.