Cyclohexane-1β,3β,5β-triol (1). A mixture of 10.9 g of phloroglucinol (Aldrich), 5 g of 5% rhodium on alumina (Engelhard), and 70 ml of 95% ethanol (distilled from Raney nickel) was shaken in an atmosphere of hydrogen at 2900 psi and 98° for 18 hr. Filtration of the hot mixture and concentration of the filtrate afforded 6.55 g (58%) of crystalline **1** as a hydrate, mp 110–112° (lit.[2] mp 110°). Anhydrous **1**, mp 185° (lit.[2] mp 184°), used in subsequent experiments, was obtained by heating the hydrate overnight at 50° (10 mm). The NMR spectrum of the original mother liquors of **1** revealed only the presence of **1** and unreacted phloroglucinol.

Cyclohexane-1β,3β,5β-triol Phenylboronate (2). A mixture of 220 ml of dioxane (distilled from $LiAlH_4$), 3.0 g (0.023 mol) of anhydrous **1**, and 2.8 g (0.023 mol) of phenylboronic acid (Aldrich) was refluxed while the dioxane–water azeotrope was slowly removed by fractional distillation over a 90-min period. Removal of the remaining solvent (ca. 150 ml) in vacuo afforded 4.9 g (99%) of **2**, mp 109–111°. Two successive sublimations (100°, 0.25 mm) gave the analytical specimen as colorless prisms: mp 114–115°; ir ($CHCl_3$) 1441 (m, B–Ar stretch[6]), 1312 cm^{-1} (s, B–O stretch[6]); NMR ($CDCl_3$) δ 1.58 (m, 3, axial methylene protons), 2.19 (m, 3, equatorial methylene protons), 4.24 (m, 3, methine protons), 7.0–7.9 (m, 5, aromatic protons); mass spectrum *m/e* 218 (M^+), 210, 186, 177.

Anal. Calcd for $C_{12}H_{15}BO_3$: C, 66.10; H, 6.93. Found: C, 66.13; H, 7.09.

Acylation of 2. The synthesis of **3b** is representative. To a solution of 1.35 g (6.2 mmol) of **2** in 15 ml of dry pyridine was added 710 μl (6.2 mmol) of benzoyl chloride. After a 2-hr period at 25° the solvents were removed *in vacuo*, and the residual solid was extracted with hot benzene. Evaporation of the extract afforded 1.95 g (99%) of crystalline **3b**, mp 125–127°. Two recrystallizations from benzene–hexane gave the analytical specimen as colorless pentagonal clusters: mp 137–137.5°; ir ($CHCl_3$) 1447 (m, B–Ar stretch), 1309 cm^{-1} (s, B–O stretch); NMR ($CDCl_3$) δ 1.5–2.8 (m, 6, $-CH_2-$), 4.48 (m, 2, –CHOB–), 5.45 (m, 1, –CHOCO), 6.5–7.9 (m, 10, aromatic protons); mass spectrum *m/e* 322 (M^+), 245, 200, 172.

Anal. Calcd for $C_{19}H_{19}BO_4$: C, 70.84; H, 5.94. Found: C, 70.82; H, 5.93.

Similarly prepared using acetic anhydride was **3a**, mp 74–75° (hexane).

Anal. Calcd for $C_{14}H_{17}BO_4$: C, 64.65; H, 6.59. Found: C, 64.64; H, 6.69.

Similarly prepared using adamantane-1-carbonyl chloride was **3c**, mp 149–151° (hexane).

Anal. Calcd for $C_{23}H_{29}BO_4 \cdot H_2O$: C, 69.36; H, 7.84. Found: C, 69.06; H, 7.69.

Monoesters 4a–c of Cyclohexane-1β,3β,5β-triol. The synthesis of **4b** is representative. To a solution of 504 mg (1.56 mmol) of **3b**, mp 125–127°, in 5 ml of dry acetone was added 1.0 ml (14 mmol) of propane-1,3-diol. The solution was stirred at 25° for 2.5 hr and then the volatiles were removed under vacuum (1 mm) overnight. The residue was taken up in 5 ml of ethyl acetate and washed with water. The organic phase was dried and evaporated, affording 306 mg (83%) of **4b**, mp 110–116°. Recrystallization from toluene gave the analytical specimen as colorless, chunky prisms: mp 114°; NMR (acetone-d_6) δ 1.35 [q, J = 11.5 Hz, 1, axial methylene proton –CHOHCH$_2$(a,e)CHOH–], 1.50 [q, J = 11.5 Hz, 2, axial methylene protons CH$_2$(a,e)CHOCOC$_6$H$_5$CH$_2$(a,e)–], 2.28 (m, 3, equatorial methylene protons), 3.83 (t of t, 2, –CHOH–), 3.93 (brs, 2, OH), 5.02 (t of t, 1, –CHOCOC$_6$H$_5$), 7.3–8.1 (m, 5, aromatic protons); mass spectrum *m/e* 236 (M^+), 218, 200, 123.

Anal. Calcd for $C_{13}H_{16}O_4$: C, 66.09; H, 6.83. Found: C, 65.90; H, 6.71.

Similarly prepared from **3a** was **4a**, mp 131–132° (acetone–hexane).

Anal. Calcd for $C_8H_{14}O_4$: C, 55.16; H, 8.10. Found: C, 54.96; H, 8.23.

Similarly prepared from **3c** was **4c**, mp 175–176° (toluene).

Anal. Calcd for $C_{17}H_{26}O_4$: C, 69.36; H, 8.90. Found: C, 69.50; H, 9.03.

Cyclohexane-1β,3β,5β-triol Tribenzoate. To a solution of 100 mg (0.75 mmol) of anhydrous **1** in 2 ml of pyridine was added 0.90 ml (7.7 mmol) of benzoyl chloride. After 1 hr at 25° the usual work-up gave 262 mg (78%) of the title compound which was recrystallized from chloroform–methanol, affording the analytical specimen as colorless prisms, mp 177–178°.

Anal. Calcd for $C_{27}H_{24}O_6$: C, 72.96; H, 5.44. Found: C, 72.79; H, 5.38.

Cyclization of 4a. A mixture of 69.5 mg of **4a** in 3 ml of toluene containing 7 mg of toluenesulfonic acid monohydrate was refluxed for 4 hr with continuous removal of water by means of a Dean-Stark trap. The solvent was removed and the residue was taken up in chloroform, washed with 2% $NaHCO_3$, dried, and the chloroform then evaporated. Sublimation (12 hr, 60°, 760 mm) of the residue afforded 24.5 mg (40%) of **5**, mp 126° (lit.[7] mp 126°).

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Registry No.—**1**, 50409-12-6; **2**, 53951-24-9; **3a**, 53951-25-0; **3b**, 53951-26-1; **3c**, 53951-27-2; **4a**, 53951-28-3; **4b**, 53951-29-4; **4c**, 53951-30-7; **5**, 27761-63-3; phloroglucinol, 108-73-6; phenylboronic acid, 98-80-6; benzoyl chloride, 98-88-4; acetic anhydride, 108-24-7; adamantyl-1-carbonyl chloride, 2094-72-6; propane-1,3-diol, 504-63-2; cyclohexane-1β,3β,5β-triol tribenzoate, 53951-31-8.

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On the Specificity of Amine Solvation

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The question arose whether proton exchange of a cyclic amine obeys the mechanism now widely accepted for acyclic aliphatic amines:[2]

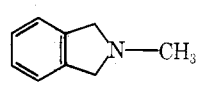
$$R_3NH^+\cdots OH_2 + HOH \underset{k_{-a}}{\overset{k_a}{\rightleftharpoons}} R_3N\cdots HOH + H_3O^+$$

$$R_3N\cdots HOH \xrightarrow{k_H} R_3N + HOH$$

$$R_3N + H_3O^+ \xrightarrow{fast} R_3NH^+\cdots OH_2$$

Since the rate parameters, especially k_H, are sensitive to subtle interactions between the water and the alkyl groups,[3] it was by no means clear how incorporating the amine into a ring would perturb the exchange process.

Proton exchange rates of *N*-methylisoindoline conjugate acid were measured by NMR line-shape analysis of the



doublet-to-singlet transition of the NCH_3 signal as the pH increased from 0 to 2. In this pH range, bimolecular exchange[4] between R_3NH^+ and R_3N was unimportant (the rate constants showed no dependence on amine concentration below the 0.15 *M* amine used in the experiments). Likewise, exchange catalyzed by hydroxide ion[4] did not contribute to the observed rates. If *N*-methylisoindoline exchanges by the mechanism shown above, then the corresponding rate equation (eq 1) predicts that a plot of $1/k_{obsd}$

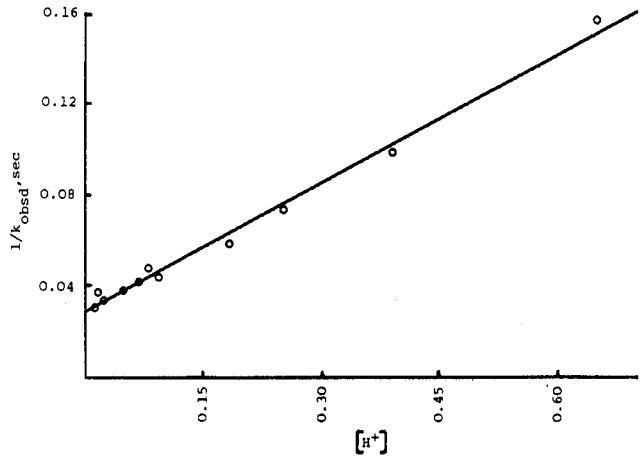


Figure 1. Plot of $1/k_{obsd}$ vs. $[H^+]$ for the proton exchange of the conjugate acid of *N*-methylisoindoline in aqueous HCl at 25°.

$$k_{obsd} = \frac{k_a k_H}{k_H + k_{-a}[H^+]} \quad (1)$$

vs. $[H^+]$ should be linear. This was found to be the case (Figure 1). The slope and intercept of the plot and the pK_a of the amine ($K_a = k_a/k_{-a}$) allowed calculation of all three rate parameters in the mechanism. These are given in Table I along with analogous data for dibenzylmethylamine. The k_a values are seen to differ sevenfold, but this largely reflects the difference in basicity between the two amines. More importantly, the k_H values for *N*-methylisoindoline and dibenzylmethylamine differ by only a small and mechanistically insignificant amount.

Table I
Proton Exchange Data for *N*-Methylisoindoline and Dibenzylmethylamine

Amine	pK_a	k_a, sec^{-1}	k_{-a}, M^{-1} sec^{-1}	k_H, sec^{-1}
N-Methylisoindoline[a]	8.33	35	7.4×10^9	1.1×10^9
Dibenzylmethylamine[b]	7.72	240	1.3×10^{10}	2.7×10^9

[a] 25°, aqueous HCl. [b] 30°, data from ref 3.

Grunwald and Ralph[3] have proposed that *solvent–solute* interactions (rather than *solvent–solvent* interactions) determine the shapes of amine solvation shells. Thus, the solvent molds itself about the contours of the amine; the better the fit, the smaller the rate of desolvation, k_H. If this description is correct, then solvation phenomena can become "extraordinarily specific".[3] Our results show that short-range London dispersion forces between the amine substituents and the water, upon which k_H depends, vary little when the substituents are confined in a ring. In at least one case, therefore, amine solvation is certainly *not* sufficiently form fitting to distinguish a cyclic amine from a conformationally different acyclic analog.[5] This work points out the need to specify the effect of shape on k_H more clearly.

Experimental Section

Materials. *N*-Methylisoindoline was prepared by reducing *N*-methylphthalimide with $LiAlH_4$ in ether in the presence of $MgSO_4$.[6] After the excess $LiAlH_4$ was destroyed with aqueous ethanol, the mixture was filtered and the ether layer was separated and dried over $MgSO_4$. The ether was then removed, leaving a dark residue which was distilled under vacuum, bp 92–93° (25 mm) [lit.[6] bp 81–82° (13 mm)], to give colorless *N*-methylisoindoline in approximately 15% yield. Redistillation gave material of high purity as judged by GLC and an elemental analysis. Although *N*-methylisoindoline was found to be oxygen sensitive to a much greater degree than simple acyclic amines, the compound was quite stable when stored under nitrogen in a freezer. The compound was also found to be stable in >1 *M* aqueous HCl (with a corresponding decrease in stability with increasing pH). All kinetic studies were performed with freshly distilled amine.

Kinetics. Observed rate constants at 25.0 ± 0.8° for NH-proton exchange of *N*-methylisoindoline in aqueous HCl were determined from the singlet-to-doublet transition of the NCH_3 NMR signal. The instrumental settings and treatment of the NMR data were similar to those described in a previous publication.[7] Rate constants in Table I determined at Emory with a Jeol JNM-MH-100 spectrometer were within 10% of those determined at Georgia with a Hitachi Perkin-Elmer R-20 spectrometer. Solutions were used immediately after their preparation, and pH values were measured both before and after each kinetic run. The pK_a of *N*-methylisoindoline (Table I) was obtained by differential potentiometric titration.

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Registry No.—*N*-Methylisoindoline, 3474-87-1.

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s-Triazines. VI.[1] Novel Reaction Products from *s*-Triazinylation of 2-Acyl-1-methylpyrroles Using 2,4,6-Trichloro-*s*-triazine

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The direct *s*-triazinylation reactions using 2,4,6-trichloro-*s*-triazine (cyanuric chloride) on pyrrole and various substituted pyrroles to give 2,4-dichloro-6-(pyrrolyl)-*s*-triazines have been described in our earlier paper.[2] Here we report on the novel reaction products obtained by treating cyanuric chloride with 2-acyl-1-methylpyrroles.

2-Acetyl-1-methylpyrrole (**3**), when treated with 1 equiv of cyanuric chloride in refluxing bromobenzene, led to an equimolar mixture of two isomeric products, **1** and **2**. The ir spectrum in either case did not show any carbonyl or hydroxyl absorptions. The NMR spectrum in CCl_4 for **1** exhibited two vinyl protons at δ 5.62 (d) and 5.77 (d) ($J \simeq 1.5$ Hz) besides the expected pyrrole ring protons. The single olefinic proton in **2** appeared as a singlet at δ 6.72 amidst a multiplet at δ 6.65–6.86 due to two other pyrrole protons. However, in C_6D_6 the olefinic proton appeared as a sharp singlet at δ 6.42 and the three pyrrole ring protons in a normal ABX pattern. Mass spectra (20 eV) for both compounds show the same parent ion, M^+ 288. The relative abundance ratios of the four peaks corresponding to the molecular ion group at 288, 290, 292, and 294 are consistent with the expected ratios 27:27:9:1 for three chlorine atoms. The loss of a chlorine atom in each case is shown by the