the second-order rate constants *vs.* pK_a of the catalyzing base. The Brønsted coefficient is 0.87. In cyclization reactions of carbamate esters having a neighboring hydroxymethyl group, buffer catalysis is not observed, the reaction involving preequilibrium ionization of the hydroxymethyl group.[2] This is most likely due to the presence of a deactivated acyl group necessitating nucleophilic attack by a fully developed negative charge. With I, however, the acyl group is not as deactivated, and proton transfer is not complete in the critical transition state, although the Brønsted coefficient of 0.87 indicates that proton transfer is appreciable.

Extrapolation of the plots of k_{obsd} *vs.* buffer concentration to zero buffer concentration gives values of the rate constants for spontaneous cyclization. The spontaneous reaction is subject to hydroxide and hydronium ion catalysis with $k_{OH} = 10^4\ M^{-1}\ sec^{-1}$ and $k_{H^+} = 3.35 \times 10^{-3}\ M^{-1}\ sec^{-1}$. Thus, the spontaneous reaction itself is a relatively facile process. In comparison, ethyl esters normally require high pH and elevated temperatures for rapid hydrolysis. In the case of ethyl benzoate, k_{OH} is $3.0 \times 10^{-2}\ M^{-1}\ sec^{-1}$ at 25° in H_2O.[5] Therefore, k_{OH} for I is approximately 10^5 greater.

It can be concluded that a neighboring hydroxymethyl group is a powerful intramolecular nucleophile in transesterification reactions even when proton transfer is only partial. The reaction of eq 1 is very likely closely analogous to the reaction of α-chymotrypsin with ethyl esters. Belke, *et al.*,[4] concluded that imidazole-catalyzed cyclization of 2-hydroxymethylbenzamide to phthalide is a good model for acylation of α-chymotrypsin by amide substrates. The present findings with ethyl 2-hydroxymethylbenzoate now make derivatives of 2-hydroxymethylbenzoic acid reasonable models for reaction of α-chymotrypsin with both ester and amide substrates.

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Hyperfine Interactions in Perturbed Nitroxides

Sir:

The stability of aliphatic nitroxides, the simplicity of their epr spectra, and, in particular, the sensitivity of their epr spectra to environmental perturbations have made them objects of considerable interest and wide application.[1] In this work we have measured the spin-Hamiltonian parameters for di-*tert*-butyl nitroxide (DTBN) and 2,2,6,6-tetramethylpiperidine-*N*-oxyl (TMPN) perturbed by molecular complex formation, by H bonding, and by solvent effects in aprotic solvents. These perturbations cause a rearrangement of the π-electron charge and spin density, increasing spin density in the 2pπ orbital of nitrogen (ρ_N^π) and altering the spin-Hamiltonian parameters.[2] From these measurements we obtain the Karplus–Fraenkel parameters,[3] Q_N and Q_{ON}^N, which relate the nitroxide ^{14}N isotropic splitting constant to ρ_N^π and ρ_O^π, respectively (eq 1).

$$a_N = Q_N\rho_N^\pi + Q_{ON}^N\rho_O^\pi \qquad (1)$$

We have also prepared a new series of free-radical molecular complexes,[2] between DTBN or TMPN and the Lewis acids MCl_4 (M = Si, Ge, Sn, or Ti) and $Ti(OPh)_4$.[4] Although TMPN is oxidized by $SnCl_4$ at room temperature,[5] complexation is observed at low temperature.

In fluid solutions, isotropic splitting constants are observed for ^{14}N, as well as for nitroxide ^{13}C and for ^{119}Sn–^{117}Sn in the $SnCl_4$ complex.[4] In frozen nitroxide solutions the epr spectra are dominated by the anisotropic ^{14}N hyperfine splitting. These powder spectra were interpreted on the basis of the spin Hamiltonian[6]

$$\mathcal{H} = \beta S\cdot \mathbf{g}\cdot H + A_N S_z I_z + B_N(S_x I_x + S_y I_y) \qquad (2)$$

using appropriate spectral features in conjunction with computer simulations.[4] A_N gives rise to well-resolved splittings and is obtained with good accuracy, but the splittings due to B_N are not resolved. We are interested in T_N, the anisotropic (dipolar) hyperfine splitting (hfs) constant; since $A_N = a_N + T_N$ and $B_N = a_N - T_N/2$,[7] T_N was obtained from values of a_N and A_N measured from fluid and frozen solutions, respectively. This procedure was verified by simulating the powder spectra with the measured A_N and a calculated value of B_N

Figure 1 gives a plot of T_N *vs.* a_N for DTBN and TMPN perturbed by a variety of interactions. Included are the results for the newly prepared free-radical molecular complexes.[4] With the exclusion of protonated DTBN (G and H), there is a linear relationship between T_N and a_N. This linear variation includes perturbation by "simple" solvent effects involving non-hydrogen-bonding solvents, points a–c, perturbation by hydrogen-bond formation, points 1–7, and also by actual molecular complex formation, points A–F. These results are similar to previous observations that variations of hfs constants are linearly related for a radical whose spin density distribution is perturbed by intermolecular interactions without structural changes in the radical.[10]

A linear least-squares fit of data for both radicals gives the straight line in Figure 1

$$a_N(G) = (0.61 \pm 0.02)T_N + (3.6 \pm 0.4) \qquad (3)$$

where the errors given are the probable errors in the slope and intercept. Because we include results from

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[1] For some recent reviews, see: (a) E. G. Rozantsev, "Free Nitroxyl Radicals," Plenum Press, New York, N. Y., 1970; (b) P. Jost and O. H. Griffith, *Methods Pharmacol.*, 2, 223 (1972).

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[7] These equations do not include the dipolar interaction between spin density on oxygen and the ^{14}N nucleus. This quantity, which can be calculated from the equations of McConnell and Strathdee[8] as modified by Barfield[9] using a self-consistently calculated value of ρ_O^π, is small ($0.66\rho_O^\pi$ G) for our perturbed nitroxides and is included in the data in Figure 1.

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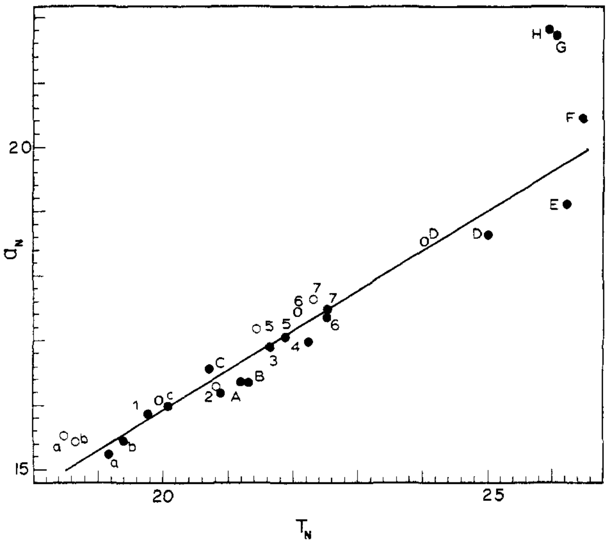

Figure 1. Plot of a_N *vs.* T_N for perturbed DTBN (●) and TMPN (○) in the aprotic solvents (a) *n*-hexane, (b) toluene, and (c) nitromethane; in the hydrogen-bonding solvents (1) decyl alcohol, (2) methanol, (3) phenol, (4) 4-fluorophenol, (5) 3-fluorophenol, (6) 1,1,1,3,3,3-hexafluoro-2-propanol, and (7) pentafluorophenol; complexed with (A) $Ti(OPh)_4$, (B) $GeCl_4$, (C) $SiCl_4$, (D) $SnCl_4$, (E) $TiCl_4$, and (F) $AlCl_3$ (G. Lozos and T. B. Eames, unpublished); protonated by (G) $H_2O \cdot TiCl_4$ and (H) $H_2O \cdot TiBr_4$.

the molecular complexes, this relationship covers a much wider range of splitting constants than is ordinarily accessible. We note that the results for a series of nitroxides oriented in host single crystals[11] are in agreement with eq 3. The values for the protonated DTBN clearly lie off the line in Figure 1. A plausible explanation for deviations at large a_N is that the perturbation of the nitroxide no longer merely causes a redistribution of charge and spin density but also causes a change in the geometry and, therefore, hybridization of the nitrogen atom.

Equation 1 can be cast in the form of eq 3 and our results used to derive the Karplus–Fraenkel parameters for the nitroxide N–O π-electron system. Obtaining ρ_N^π from T_N ($\rho_N^\pi = T_N/T_N^0$), where T_N^0 is the anisotropic (dipolar) ^{14}N hfs constant for a single electron in a nitrogen 2pπ orbital, and using the spin density normalization ($\rho_N^\pi + \rho_O^\pi \cong 1$), eq 1 becomes

$$A_N = \frac{(Q_N - Q_{ON}^N)}{T_N^0} T_N + Q_{ON}^N \qquad (4)$$

Equating eq 3 and 4, we find $Q_{ON}^N = 3.6 \pm 0.4$ G, independent of T_N^0. Q_N is evaluated by using $T_N^0 = 33.5$ G, calculated from an unrestricted Hartree–Fock nitrogen 2p orbital:[12,13] $Q_N = 24.2 \pm 1.1$. The values reported here, based on more extensive results and corrected for the oxygen dipolar interaction,[7] are to be preferred over our preliminary estimates reported in ref 2.

The value of Q_N, for a trigonal nitrogen bonded to oxygen and to two aliphatic carbons, depends on a calculated value for T_N^0. The value of Q_{ON}^N for trigonal nitrogen bonded to oxygen is obtained without assumptions about the magnitudes of σ–π parameters and without using valence-theory calculations of π-electron wave functions. Only once previously has a similar parameter been obtained without recourse to calculations: $Q_{CN}^N = 2.62$ for protonated diazines.[15] Both Q_{CN}^N and Q_{ON}^N are positive, contrary to simple considerations of spin polarization which take into account only L-shell orbitals on N and O.

We note that Q_{ON}^N is of appreciable magnitude, although some earlier studies suggested that it could be neglected.[16,17] It is conceivable that Q_{ON}^N is also significant for nitro and nitroso aromatic anions, and that the value of Q_{ON}^N is transferable.

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(13) Using this value for T_N^0 we find ρ_N^π for DTBN or TMPN in nonpolar solvents to be about 0.5, whereas previous estimates have ranged from 0.8–0.9 down to 0.3–0.4.[14]

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(18) National Defense Education Act Predoctoral Fellow, 1969–1972.

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Synthetic Studies by the Use of Carbonates. IV.[1] A New Method for the Synthesis of Glycosyl Compounds by the Use of 1-*O*-Aryloxycarbonyl Sugar Derivatives

Sir:

Acyclic alkyl aryl carbonates have been shown to undergo pyrolysis at high temperatures above 200° to give the corresponding alkyl aryl ether.[2] These facts were considered to suggest that the replacement of the alkoxy moiety of the alkyl aryl carbonates with a hemiacetal moiety such as the glycosyloxy substituents might bring about a considerable enhancement of their reactivity. The expectation was substantiated by the fact that the pyrolysis of 2,3,4,6-tetra-*O*-acetyl-1-*O*-phenoxycarbonyl-β-D-glucopyranose (**1**)[3,4] at 170° followed by chromatography on a column of silica gel afforded phenyl 2,3,4,6-tetra-*O*-acetyl-β-D-glucopyranoside (**2**)[5] in 46%, diphenyl carbonate (**3**) in 11%, and bis(2,3,4,6-tetra-*O*-acetyl-β-D-glucopyranose) 1,1′-carbonate (**4**)

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(3) **1** was prepared from 2,3,4,6-tetra-*O*-acetyl-D-glucopyranose (P. Z. Allen in "Method in Carbohydrate Chemistry," Vol. 1, R. L. Whistler, Ed., Academic Press, New York, N. Y., 1962, p 372) by treating with phenyl chloroformate in pyridine, mp 114–115°, $[\alpha]^{22}D$ −11° (*c* 1.0, $CHCl_3$), and the analytical data were consistent with the expected structure.

(4) **1** was found to be pyrolyzed even at 160° in contrast with the usual alkyl aryl carbonates.

(5) Mp 126–126.5°, $[\alpha]^{22}D$ −20° (*c* 1.0, $CHCl_3$) [B. Helferich und E. Schmitz-Hillebrecht, *Ber.*, **66**, 378 (1933); mp 124–125°, $[\alpha]D$ −22° ($CHCl_3$)].