Durabond DB-5; carrier gas, helium at 0.6 bar; column temperature, 130–280 °C at 4 °C/min). Low-resolution mass spectra were obtained with a Ribermag R-10-10 quadrupole mass spectrometer using the "SADR" (simultaneous acquisition and data reduction) data system (source temperature, 200 °C; reagent gas for chemical ionization, NH_3). High-resolution mass spectra were recorded at the mass spectrometry laboratory of the University of Minnesota on a VG 7070E-HF instrument (negative chemical ionization mode, source temperature 150 °C, NH_3 as reagent gas). FTIR spectra were obtained on a Nicolet Model 7199 Fourier transform spectrometer.

Incorporation experiments were conducted on the live, whole sponge in Monterey Bay Aquarium at Hopkins Marine Station by incubation in an aerated precursor-seawater solution for 3 days during November and March. For radioactivity measurements, aliquots (usually $^1/_5$–$^1/_{10}$) of the ^{14}C-labeled material were dissolved in 10 mL of organic counting scintillant (OCS), and the radioactivity was measured with a Beckman LS 7500 liquid scintillation system. All results were corrected for background radiation, calculated to the proportionate amount, and presented as disintegrations per minute by using a standard solution. All precursors used were tested for radioactive purity by means of blank HPLC experiments.

Debromination of (5*E*,9*Z*)-6-Bromo-5,9-hexacosadienoic Acid Methyl Ester (1b). To a suspension of lithium aluminum hydride (1 mg) in dry ether (1 mL) was added dropwise a solution of the ester **1b** (3 mg) in dry ether (1 mL) at 0 °C, and the mixture was stirred at that temperature for 1 h. Addition of a slight excess of oxalic acid dihydrate and filtration yielded a product that was reacted crude, after solvent removal, with excess *sec*-butyllithium in dry THF–hexane–ether (2:1:1 mixture, 2 mL) at 0 °C under nitrogen for 1 h. Absolute methanol was then added to quench the reaction. The crude dried product was dissolved in acetone (2 mL) and titrated with Jones reagent. The reaction mixture was then diluted with water (3 mL) and extracted with ether. The resulting acid was converted to the methyl ester by reflux with 14% BF_3–MeOH. The final product, after being extracted with hexane–ether (10:1) and purified by silica gel–Florisil open column chromatography, was identified to be **2b** by comparison on GC with an authentic sample. The other possible stereoisomer in this case, the (5*E*,9*Z*)-$\Delta^{5,9}$-26:2 methyl ester,[28] had a shorter GC retention time and was not detected.

(5*E*,9*Z*)-6-Bromo-5,9-hexacosadienoic Acid Methyl Ester (1b): ca. 5 mg, oil, from 30 g of dried sponge; HPLC relative retention time, 0.97 (**2b**: 1.00) under the above-stated instrumental conditions; ^1H NMR (400 MHz, $CDCl_3$) 5.84 (t, J = 7.6 Hz, 1 H, C-5), 5.41 (m, 1 H, C-10), 5.32 (m, 1 H, C-9), 3.67 (s, 3 H, OMe), 2.45 (t, J = 7.4 Hz, 2 H, C-7), 2.32 (t, J = 7.6 Hz, 2 H, C-2), 2.30 (m, 2 H, C-8), 2.08 (m, 2 H, C-4), 2.04 (m, 2 H, C-11), 1.71 (quin, J = 7.4 Hz, 2 H, C-3), 1.26 (m, 28 H, C-12–C-25), 0.88 (t, J = 7.0 Hz, 3 H, C-26); EIMS m/z (relative intensity) 405 (100), 373 (23.3), 355 (9.6), 331 (9.8), 264 (86.5); CI-MS-NH_3 (positive) 504 (100), 502 (98.9), 405 (25.5); CI-MS-NH_3 (negative) 486 (38.7), 484 (53.6), 485 (58.3), 483 (56.0), 405 (47.1); EI-MS (acid pyrrolidide) 525 (0.3), 523 (0.3), 444 (60.4), 260 (18.4), 258 (17.6), 180 (7.7), 113 (100); IR (CCl_4) (cm^{-1}) 2920, 2850 (=CH, CH_3, CH_2), 1740 (C=O), 1460, 1430 (=CH, CH_3, CH_2), 1210, 1160 (CO); high-resolution MS (negative DCI mode, NH_3 as reagent gas) calcd for $(M - H)^-$ where M = $C_{27}H_{49}O_2Br$ 485.2887 and 483.2907, found 485.2855 and 483.2851 (intensity ratio 1:0.89).

Abbreviations: DCI-MS, desorption chemical ionization mass spectrometry; CI/EI-MS, a combination of electron-impact and chemical-ionization mass spectrometry.

Acknowledgment. Financial support was provided by the National Science Foundation (Grant No. DMB 8606249) and the National Institutes of Health (Grant No. GM 28352). Use of the 400-MHz NMR spectrometer was made possible by NSF Grant No. CHE 81-09064. We thank Prof. Robert Simoni of the Stanford Biology Department for the use of his liquid scintillation counter; Dr. Laszlo Szilagyi of the Stanford Magnetic Resonance Laboratory for 2D-NMR measurements; Annemarie Wegmann-Szente for obtaining low-resolution MS data; Dr. Welton Lee of W. L. Lee & Associates, Inc., San Francisco, CA (Consultants in Biology, Geology and Palentology), for taxonomic classification of the sponge; Dr. C. Harrold (Hopkins Marine Station) and Dr. J. Watanabe (Monterey Bay Aquarium) for assistance with facilities; and Max Hoberg, Dr. Russell Kerr, and Christopher Silva for collection of sponge specimens and help in the incorporation experiments.

Synthesis and Characterization of a Novel Betaine Dye: 2,4-Dimethyl-6-(2,4,6-triphenyl-*N*-pyridinio)phenolate

M. S. Paley,* E. J. Meehan, C. D. Smith,[†] F. E. Rosenberger, S. C. Howard, and J. M. Harris*

Department of Chemistry and Center for Microgravity and Materials Research, University of Alabama in Huntsville, Huntsville, Alabama 35899

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A pyridinium *N*-phenoxide betaine with the pyridine ring attached at the ortho position of the phenoxide ring was synthesized via the procedure of Reichardt for making para betaines. The dye was found to be highly solvatochromic, which is indicative of a large dipole moment change upon excitation. Crystals of the betaine were grown, and the structure was determined by X-ray analysis. Interestingly, the pyridine and phenoxide rings are orthogonal, in apparent conflict with the observed movement of electron density between the two rings upon excitation. Possible mechanisms for interaction between orthogonal rings are discussed.

Introduction

Pyridinium *N*-phenoxide betaine dyes, first synthesized in the 1920s[1] and studied in depth by Reichardt and Dimroth in the 1960s,[2–4] are of interest for several reasons. They are unusual in that their electronic ground state exists as a dipolar ion, with the nitrogen atom carrying a positive charge and the oxygen atom carrying a negative charge. As a consequence they possess very large ground-state dipole moments, which decrease significantly upon excitation because of intramolecular charge transfer. This causes them to be highly solvatochromic,[5,7] i.e., their

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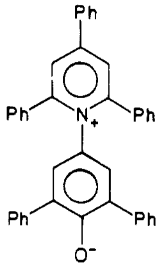
Table I. Solvatochromic Data for Ortho Betaine

solvent	wavelength, nm	wavenumber, cm^{-1}	color
ethanol (25% aq)	470	21 227	orange
ethanol (50% aq)	488	20 492	orange
ethanol (95% aq)	522	19 157	violet
ethanol (absolute)	530	18 868	violet
methanol	500	20 000	red
2-propanol	558	17 921	blue-violet
dimethyl sulfoxide	640	15 625	blue
acetone	636	15 723	blue
acetonitrile	622	16 077	blue
pyridine	653	15 314	blue-green
dichloromethane	652	15 337	blue-green
chlorobenzene	680	14 706	green-blue
1,4-dioxane	690	14 493	green
benzene (dry)	715	13 986	green-yellow
benzene (0.02% H_2O)	625	16 000	blue

UV–visible absorption spectra are highly solvent dependent. In fact, the dye 2,6-diphenyl-4-(2,4,6-triphenyl-*N*-pyridinio)phenolate, 1, also known as ET-30 or Reichardt's dye, has one of the largest solvatochromic shifts in absorption maxima ever observed.[2,5] In water this dye has a maximum at 453 nm and in diphenyl ether it has a maximum at 810 nm, a shift of 357 nm. Because of their solvatochromism these betaines have often been used to characterize the polarity of solvents,[2,3,6,8–10] and to spectrophotometrically determine the amount of water in organic solvents.[11,12] The large dipole moment difference between ground and excited states also makes them of interest for applications in nonlinear optics, such as second harmonic generation (doubling the frequency of laser radiation).[13]

Most pyridinium *N*-phenoxide betaines that have been studied in depth and reported in the literature have had the pyridine ring attached at the position para to the oxygen atom of the phenoxide ring. Nonetheless, betaines with the pyridine ring attached at the sterically hindered ortho position have also been synthesized.[14,15] In contrast to the para betaines, however, these compounds have received little attention. In the current work we report the synthesis of the ortho-substituted betaine 2,4-dimethyl-6-(2,4,6-triphenyl-*N*-pyridinio)phenolate, 2, hereafter referred to simply as the ortho betaine. In addition we have characterized this compound solvatochromically, grown crystals by both solution and vapor transport methods, and determined the crystal structure by means of X-ray diffraction.



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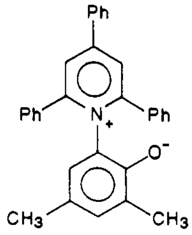

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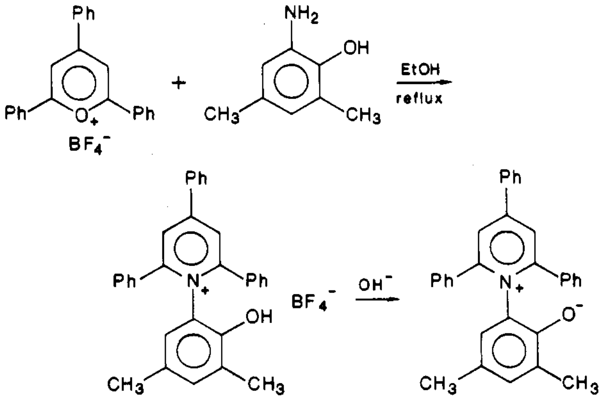
Results and Discussion

The synthesis of the ortho betaine proceeded straightforwardly by following essentially the same procedure that Reichardt used to synthesize para substituted betaines[2] (eq 1). The reaction time for the coupling step was longer (overnight, as compared to a few hours for the para betaines) to allow for the possibility that the rate may be slower because of increased steric hindrance for formation of the ortho betaine. The workup procedures used here for purifying the fluoroborate salt and isolating the dye were slightly modified from those used by Reichardt; this was done for convenience, and we have used these same modifications in the synthesis of para betaines. The structure of the ortho betaine was confirmed by NMR and X-ray crystallography. The yield was about 50% of theoretical.



(1)

The solid ortho betaine dye, left behind upon evaporation of its chloroform solution, is a gray-violet powder. It is essentially insoluble in water, but it readily dissolves in most organic solvents, even a very nonpolar solvent such as benzene. This is one difference between the ortho betaine and its para counterpart, 2,6-dimethyl-4-(2,4,6-triphenyl-*N*-pyridinio)phenolate. The para betaine is soluble in water and virtually insoluble in benzene. Like the para betaines, the ortho betaine is highly negatively solvatochromic (Table I), i.e., polar solvents shift its UV–visible absorption to shorter wavelengths and nonpolar solvents shift it to longer wavelengths. In 25% aqueous ethanol the dye has a maximum at 470 nm and in dry benzene it has a maximum at 715 nm. The presence of even small amounts of water causes significant shifts in the absorption maximum, especially in nonpolar solvents such as benzene. When the spectrum was obtained in benzene containing about 0.02% water, the maximum shifted to 625 nm. This large shift suggests that the ortho betaine might be useful for the spectrophotometric determination of water in nonpolar solvents in which many of the para betaines are not very soluble. The one drawback to the use of the ortho betaine for this purpose is that its solvatochromic charge transfer band is relatively weak, i.e., it has a small molar extinction coefficient. The extinction coefficient of this band is 360 in acetonitrile, as compared to about 1270 for the corresponding para betaine in the same solvent. Hence more concentrated solutions of the ortho betaine would be needed for water determination.

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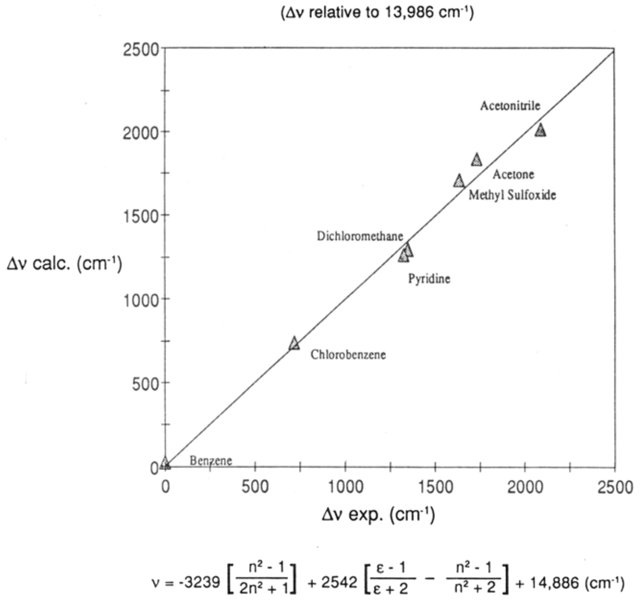

Figure 1. Solvatochromism data for ortho betaine fit to the McRae equation.

The solvatochromic shifts in absorption maximum of the dye in all solvents, except alcohols and dioxane, were fitted by linear regression to the McRae equation:[16,17]

$$\nu_s - \nu = A\left[\frac{n^2-1}{2n^2+1}\right] + B\left[\frac{\epsilon-1}{\epsilon+2} - \frac{n^2-1}{n^2+2}\right]$$

$$B = \frac{2\mu_g(\mu_g - \mu_e)}{4\pi a^3 h \epsilon_0}$$

where ν_s is the frequency of transition in a solvent, ν is the frequency of transition in vacuum, ϵ is the static dielectric constant of the solvent, n is the refractive index of the solvent, A and B are constants, μ_g and μ_e are, respectively, the ground- and excited-state dipole moments of the solute, ϵ_0 is the permittiity of vacuum, h is Plank's constant, and a is the radius of a spherical cavity that the molecule occupies in the solvent. By measuring ν_s in a variety of solvents with known n and ϵ and fitting the data by linear regression to this equation, one can obtain values of the constants A and B, as well as ν (however, the uncertainty in the value of ν is greater than that in the values of A and B). The McRae equation is based solely on an electrostatic model of the solute–solvent and solvent–solvent interactions; no other type of interaction is taken into account. Hence solvents in which there is some specific interaction between solvent and solute, or between solvent molecules themselves, are not included when fitting data to the McRae equation. Thus hydroxylic solvents, such as alcohols, are excluded because of their hydrogen bonding. Dioxane is excluded because its behavior (polarity) is not adequately described by only its dielectric constant and refractive index.[17] As seen in Figure 1, the fit of the data for the ortho betaine to the McRae equation is good. The constant B is an indication of how much the dipole moment of the molecule changes from the ground state to the Frank–Condon excited state. The greater B is, the greater the change. Note that the magnitude of B for the ortho betaine is quite large (2500), indicative of a significant dipole moment change upon excitation. We also note that the sign of B is positive, indicating that the dipole moment of the excited state is less than that of the ground state, as expected for a negatively solvatochromic molecule. Because the magnitude of the ground-state dipole moment has not yet been determined for this dye, we cannot compute a value for the excited-state dipole moment.

Table II. Some Selected Bond Lengths and Dihedral Angles for Compound 2

joined atoms	bond lengths, Å	atoms	dihedral angles, deg
C_1–N_1	1.47	$C_{13}N_1C_1C_2$	90.0
C_2–O_1	1.29	$C_9N_1C_1c6$	80.8
C_5–C_8	1.49	$N_1C_9C_{14}C_{15}$	58.1
C_3–C_7	1.49	$N_1C_{13}C_{26}C_{27}$	58.3
C_9–C_{14}	1.49	$C_{10}C_{11}C_{20}C_{21}$	27.6
C_{11}–C_{20}	1.49	–	–

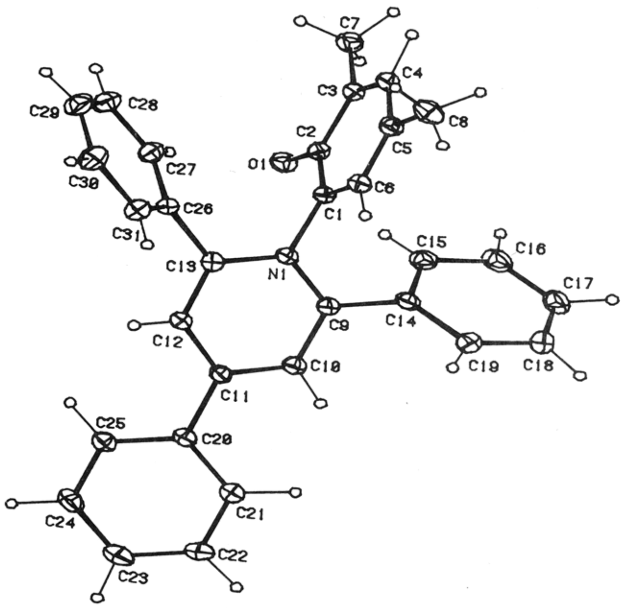

Figure 2. Crystal structure of the ortho betaine.

The crystals of the ortho betaine grown from solution were compared under a microscope with those grown by vapor transport, and both crystal habits appeared to be identical. Thus we expect that the solution-grown crystals should have the same structure as the vapor-grown ones; at present, however, we have not collected any X-ray data on the solution crystals to confirm this. The crystal chosen for the structure determination was grown by vapor transport. The space group of the ortho betaine crystal was determined to be P_{bca}, thus the crystal is centrosymmetric.

One interesting feature of the crystal structure (Table II, Figure 2) is that the pyridine ring and the phenoxide ring are twisted out of plane by essentially 90° (an X-ray analysis on a para betaine showed these rings to be twisted out of plane by 65°).[18] In view of steric factors this conformational preference is not surprising, but it raises the question of how the pyridine ring and the phenoxide ring interact to transfer charge and decrease the dipole moment upon excitation. Clearly the usual (e.g., as in nitroanilines) conjugative transfer of charge from an electron-donating to an electron-accepting part of the molecule is ruled out here (i.e., as in **3**).

Interaction between perpendicular π-systems is not unprecedented. For example, the phenomenon of spiroconjugation, first described in 1967,[19,20] involves interaction

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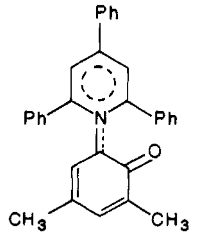

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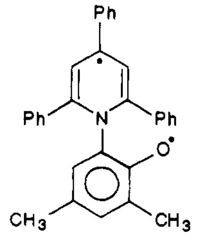

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of two orthogonal π-rings sharing a common sp^3 hybridized carbon. The result of this interaction is either a stabilization or a destabilization of the ground state, which is reflected in several experimentally observable phenomena. Possibily a related type of interaction is occurring in the betaine excited state, although the separation between the two rings is probably too large for this to be significant.

A more likely possibility for the observed reduction of dipole moment is an intramolecular charge-transfer process analogous to that observed for UV–vis absorption by charge-transfer complexes such as the pyridinium iodides.[21] In this case an electron would be transfered through space from the phenoxide ring to the pyridine ring, and the excited state would have diradical character such as shown in 4.

It is also interesting that the carbon–oxygen bond length for the ground state of the ortho betaine, 1.29 Å (the same as for the para betaine),[18] is very short for a single bond and is in fact almost as short as a full carbon–oxygen double bond. Thus a significant amount of negative charge must be delocalized into the phenoxide ring. On the other hand, the carbon–nitrogen bond length, 1.47 Å (also the same as for the para betaine),[18] is normal for a carbon–nitrogen single bond, indicating that there is little if any conjugation in the ground state between the phenoxide ring and pyridine ring.

Lastly it should be mentioned that it is possible that the geometry of the betaine in the crystal is different from that in solution; i.e., in solution perhaps the rings are sufficiently coplanar that "normal" π-orbital interactions take place that would account for the reduction of dipole moment upon excitation. Support (albeit weak) for this possibility comes from the observation of Allinger and co-workers that biphenyls are more nearly planar in the gas phase than in the solid phase.[22]

Future work in our laboratory will be concerned with applying theoretical methods to elucidate this question of electronic distribution in the ground and excited states of the betaines.

Experimental Section

All reagents were purchased from Aldrich and used without further purification. The NMR apparatus used was an IBM-Bruker 200 MHz, Fourier transform spectrometer. The UV-visible spectra were obtained using an HP 8452A photo diode array spectrometer.

Synthesis of Ortho Betaine. A solution of 1.4 g of 2,4,6-triphenylpyrylium tetrafluoroborate, 0.65 g of 2,4-dimethyl-6-aminophenol, and 0.8 g of sodium acetate trihydrate in 25–30 mL of 95% ethanol was heated overnight under reflux. The solution was cooled and 8–10 mL of 60% aqueous fluoroboric acid was added. This solution was added to 100–150 mL of water and refrigerated overnight, to "knock" the crude fluoroborate salt of the ortho betaine out of solution (often as a lump). The crude salt was dissolved in 10–20 mL of glacial acetic acid (heating was sometimes necessary), and this solution was added dropwise, very slowly at first, to 100–150 mL of stirred anhydrous ethyl ether, which precipitated the salt as a yellow solid. The salt was removed by filtration, dried, dissolved in 10–15 mL of methanol, and again precipitated from ether. This step was repeated a second time, and the precipitate was filtered and dried, yielding about 1 g (50%) of pure fluoroborate salt of the ortho betaine. ^1H NMR (in acetone-d_6): 8.59 (s, 2 H, 3,5-H of pyridine ring), 8.30–8.34 (m, 2 H), 7.39–7.72 (m, 13 H), 7.16 (s, 1 H); 6.85 (s, 1 H), 2.90 (s, 1 H, OH), 2.02 ppm (s, 6 H, CH_3).

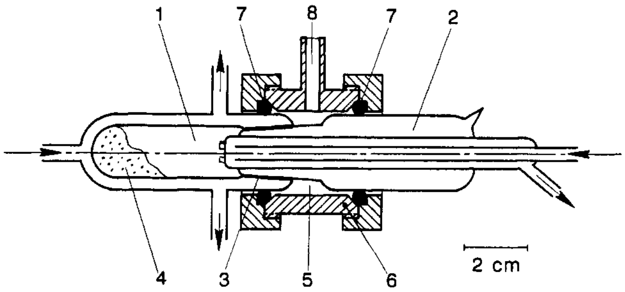

Figure 3. A schematic representation of the glass vapor growth cell for crystallization of the ortho betaine.

To convert the salt into dye, 1 g of the purified salt was dissolved in 75 mL of methanol, 10 mL of 10% sodium methoxide in methanol was added, and the solution was heated for 5–10 min. The solution was added to 200 mL of 10% aqueous NaOH and refrigerated overnight, causing the dye to come out of solution. The dye was extracted into five or six 100-mL portions of chloroform (forming a blue solution), which were then combined, washed with two 50–100-mL portions of water, and dried over anhydrous sodium sulfate. Upon evaporation of the chloroform and drying in vacuum the pure ortho betaine, **2**, was left as a gray-violet solid. Yield: 0.9 g. ^1H NMR (in $CDCl_3$): 7.96 (s, 2 H, 3,5-H of pyridine ring), 7.79–7.84 (m, 2 H), 7.27–7.61 (m, 13 H), 6.57 (s, 1 H), 6.10 (s, 1 H), 2.96 (s, H_2O of crystallization), 1.98 (s, 3 H, CH_3), 1.83 ppm (s, 3 H, CH_3).

Solvatochromic Measurements. All solvents were anhydrous, gold label quality (Aldrich), dried over 3-Å molecular sieves, except for benzene and dioxane, which were dried over 4-Å sieves,[23] and the aqueous solvents, which, of course, were not dried. A dilute solution of the ortho betaine was prepared in each solvent (about 10 mL), and the nonaqueous solutions were dried over molecular sieves to remove any water present that came from the dye (such as water of crystallization). The UV–visible absorption spectrum of each solution was obtained in the range 200–800 nm. The longest wavelength absorption band is the highly solvatochromic charge transfer band. The maximum of this band was determined in each solvent (Table I), and the data, omitting the hydroxylic solvents and dioxane, were then fitted by means of linear regression to the McRae equation (Figure 1). The molar extinction coefficient was measured as 363 in acetonitrile, using solutions at four concentrations and fitting the data to Beer's law.

Solution Crystal Growth. A small amount of the ortho betaine (about 0.2 g) was dissolved in a minimum amount of hot 50% v/v aqueous ethanol. The solution was then packed in styrofoam and placed overnight in the refrigerator to allow slow cooling to around 0 °C, yielding small, violet, needlelike crystals of the dye.

Vapor-Phase Crystal Growth. The crystals were grown from the vapor with the "diffusionless" physical vapor growth technique.[24,25] A schematic presentation of the glass vapor growth cell is shown in Figure 3. The cell consists of two thermostated parts (1, 2) which are connected via a pair of ground joints (3). The ortho betaine powder (4) is placed into the source chamber (1), which is then connected to the cold finger (2). A Teflon sleeve (0.1-mm thickness) prevents seizing of the nonlubricated ground joints (3). To provide for a small leak from the growth chamber

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to the vacuum space (5), the Teflon sleeve was sliced, leading to a gap approximately 0.5-mm wide. The vacuum space is formed by a Cajon vacuum union (6), the o-rings (7) of which seal against the glass parts of the cell. A vacuum port (8), soldered to the union (6), is connected to a liquid nitrogen trapped mechanical vacuum pump. The temperature in the source chamber (1) and the cold finger (2) is controlled to within 0.5 °C through silicone oil circulating from two independent thermostated baths. Heat transfer between these two parts is minimized by a vacuum jacket surrounding the cold finger. Thus a relatively steep temperature gradient is established in the vapor at the flat end of the cold finger, which restricts nucleation and growth of the crystals to this limited region.

The leak from the growth chamber serves two purposes. First, at room temperature and during heat-up to growth temperature the leak allows for the thorough in situ drying and outgassing of the starting material and cell interior. This feature proved particularly useful for the ortho betaine, which had adsorbed water present from its synthesis. Second, and even more important, the continuous efflux of gaseous components from the cell at growth temperatures maximizes the transport rate.[24] This, in turn, is particularly important for growth of crystals with limited thermal stability, since it allows for significant transport at low vapor pressures; i.e., low temperatures.

Nucleation and growth on the flat face of the cold finger were monitored through a long focal length microscope (30×). Exploratory runs showed that the growth of the well-faceted crystals, i.e., attainment of sufficient surface mobility of adatoms,[26] required growth temperatures of 120 °C. The onset of nucleation, within a few hours after an increase of the source temperature above that of the cold finger, typically required temperature differences of 60 °C. As soon as nucleation of 1–5 crystallites was observed, this temperature difference was reduced to around 10 °C to promote growth without further nucleation. The growth of 2–3-mm sized crystals typically required 3–5 days, during which the temperature of the ortho betaine source material was slowly increased by a total of 2–4 deg. After growth, the crystals were cooled down from the growth temperature within a few hours.

Crystal Structure Determination. A crystal of the ortho betaine was mounted on a glass fiber in air using epoxy cement. Weissenberg photographs revealed the crystal to be orthorhombic P_{bca}. The density was measured by flotation in hexane/Freon 112, $D_m = 1.217$ (1) g/cm^3, $D_x = 1.219$ g/cm^3. Data were collected at room temperature on a CAD-4 X-ray diffractometer using Cu K radiation. Accurate cell dimensions and orientation matrix were obtained by centering 25 reflections with $2\theta > 40°$; $a = 11.723$ (1), $b = 22.264$ (2), and $c = 17.853$ (2) Å; $Z = 8$. Intensity data were collected in $\omega/2\theta$ scan mode for 2894 reflections. Intensity checks on three standards indicated no decay during data collection. Absorption corrections were not applied. The structure was solved by direct methods using the crystallographic computer package XTAL2.2.[27] The structure was refined by full-matrix least-squares methods with anisotropic temperature factors for all nonhydrogen atoms. All hydrogen atoms were located in a difference Fourier map and their coordinates and isotropic thermal parameters refined. The final conventional R index was 0.057; the final difference map contained no significant unaccounted density. The list of final atomic coordinates, atomic thermal parameters, and molecular dimensions have been deposited as supplementary material.

Registry No. 2, 120712-61-0; 2,4,6-triphenylpyrylium tetrafluoroborate, 448-61-3; 2,4-dimethyl-6-aminophenol, 41458-65-5; sodium acetate, 127-09-3; fluoroboric acid, 16872-11-0.

Supplementary Material Available: Tables of non-hydrogen atom coordinates, hydrogen atom parameters, non-hydrogen thermal parameters, and bond lengths (4 pages). Ordering information is given on any current masthead page.

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Alkyltransferase Model Reactions: Synthesis of Sulfonium and Ammonium Compounds Containing Neighboring Nucleophiles. Kinetic Studies of the Intramolecular Reaction of Amino, Hydroxy, Phenoxy, and Mercapto Onium Salts

Robert J. Miller, Athan Kuliopulos, and James K. Coward*,†

Department of Chemistry, Rensselaer Polytechnic Institute, Troy, New York 12180-3590

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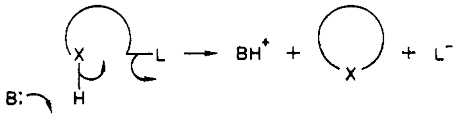
The synthesis of a series of sulfonium and ammonium salts containing a variety of neighboring nucleophiles is described. Several of these molecules undergo facile cyclization reactions with rate enhancements of ca. 10^5 over the corresponding intermolecular reaction. Investigation of the reaction kinetics showed that these intramolecular nucleophilic reactions obey the Brønsted relation with $\beta = 0.34$ for the sulfonium series and $\beta \geq 0.49$ for the ammonium series. Buffer catalysis is observed in several of these reactions, but a consistent trend is not apparent. Activation parameters have been determined in order to examine the importance of an entropic driving force in intramolecular reactions.

As part of our research on the mechanism of enzyme-catalyzed alkyl transfer reactions, we wished to extend our previous observations[1-3] on the possible role of general catalysis in these reactions. In order to probe the structural requirements in the reaction shown in eq 1, the synthesis of molecules containing a variety of appropriately positioned nucleophiles (X) and leaving groups (L) was required. To this end we have developed methods for the synthesis of substituted thioanisoles and N-methylanilines



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† Present address: Departments of Chemistry and Medicinal Chemistry, The University of Michigan, Ann Arbor, MI 48109.

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