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An Unusually Acidic Methyl Group Directly Bound to Acridinium Cation

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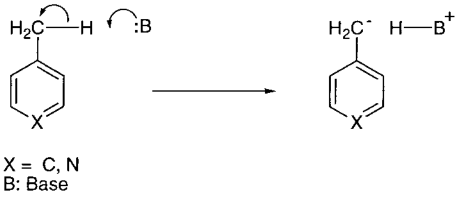
9,10-Dimethylacridinium chloride (**1**: X = Cl) exhibited strong acidity of pH 3.90 (3.4×10^{-3} M, 20 °C) in an aqueous solution. H−D exchange reaction of **1** in D_2O indicated that protons in the 9-methyl group dissociated to generated H^+ ions. This is a unique example of a methyl proton functioning as an acid. The acidity derives from the wider π face in acridinium capable of delocalizing the newly formed negative charge upon proton dissociation. PM3 calculations provided stabilization factors ($\delta\Delta H_f°$) between proton dissociated and undissociated forms of several N-heterocycles and also confirmed the acidity observed in acridinium.

Introduction

Several aromatics undergo H−D exchange reaction of protons in a methyl side chain which is covalently bound to the aromatic ring. The mechanism of this type of reaction could be considered as being initiated by nucleophilic attack of a base ion on a methyl hydrogen resulting in heterolytic cleavage of the C−H bond to afford a carbanion and a proton (eq 1). Consequently, the presence of a strong base and/or vigorous conditions such as high temperature are inevitably required.[1] Among aromatic nuclei, acridines and their derivatives are still attracting considerable attention because of the many functions which they possess, including biomimetic redox reactivities,[2] chemiluminescence,[3] and the interaction with DNA as an intercalator.[4] In particular the 9 position, the pare position from acridine nitrogen, in acridinium exhibits strong electrophilicity and reacts with alcohols giving rise to 9-alkoxyacridanes.[5] 9-Methyl-substituted acridinium exhibited a slightly different reactivity with basic alcohol, affording the corresponding 9-alkoxyacridanes[6,7] followed by an olefinic species, 9-methyleneacridane, through the 9-methyl proton abstraction by an alkoxide.[6] Therefore, the 9 position in acridinium appears to have different electric and steric conditions as compared to the other positions, giving rise to expectations of more unique reactivity. Here we report on the unusual acidity of protons in methyl groups substituted onto acridinium skeleton at the 9 position (**1**).[8] The pK_a of these methyl protons was estimated to be slightly higher than that of acetic acid at room temperature, showing that the methyl protons in **1** are functioning as an organic protic acid.



(1)

Results and Discussion

9,10-Dimethylacridinium chloride (**1**: X = Cl) undergoes facile and spontaneous H−D exchange reaction of protons in the 9-methyl group under neutral and mild conditions affording deuterated acridinium (**2**) quantitatively (eq 2). The ^{1}H NMR spectrum of **1** (X = Cl, 1.85×10^{-2} M) showed disappearance of the proton resonance of the 9-methyl group (2.89 ppm), but not of any other resonances after being placed at 60 °C for 10 h in D_2O (Figure 1). The ^{13}C NMR spectrum in the complete ^{1}H-decoupled condition also indicated disappearance of the 9-methyl ^{13}C signal (15.6 ppm) without any change in other ^{13}C resonances (Figure 1). In contrast, no obvious electronic spectrum change in the UV−vis region (200−800 nm) was observed during the course of reaction at 60 °C as well as after this reaction period measure at 25 °C. Mass spectrometry (MALDI-tof) of the reaction product showed a molecular ion peak at m/z = 211.1

$$\mathbf{1} \xrightarrow[\substack{k_{obs}(60\ °C) = 4.25 \times 10^{-5}\ sec^{-1} \\ Ea = 63.5\ kJ/mol}]{D_2O} \mathbf{2} \qquad (2)$$

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[1] (a) Hoffmann, J. E.; Muller, R. J.; Schriesheim, A. *J. Am. Chem. Soc.* **1963**, *85*, 3000−3002. (b) Kawazoe, Y.; Ohnishi, M.; Yoshioka, Y. *Chem. Pharm. Bull.* **1967**, *15*, 1225−1231.

[2] Fukuzumi, S.; Suenobu, T.; Kawamura, S.; Ishida, A.; Mikami, K. *Chem. Commun.* **1997**, 291−292 and references therein.

[3] (a) Imanishi, T.; Ueda, Y.; Tainaka, R.; Miyashita, K.; Hoshino, N. *Tetrahedron Lett.* **1997**, *38*, 841−844. (b) Lee, C.; Singer, L. A. *J. Am. Chem. Soc.* **1980**, *102*, 3823−3829. (c) White, E. H.; Suzuki, N.; Hendrickson, W. H. *Chem. Lett.* **1979**, 1491−1494.

[4] Slama-Schwok, A.; Teulade-Fichou, M.-P.; Vigneron, J.-P.; Taillandier, E.; Lehn, J.-M. *J. Am. Chem. Soc.* **1995**, *117*, 6822−6830 and references therein.

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[6] (a) Kano, K.; Zhou, B.; Hashimoto, S.; Sugino, T.; Torii, A. *Chem. Express* **1987**, *2*, 13−16. (b) Bunting, J. W.; Meathrel, W. G. *Can. J. Chem.* **1974**, *52*, 981−987.

[7] Zimmermann, T.; Abram, U.; Schmidt, K. *J. Heterocycl. Chem.* **1998**, *35*, 787−793.

[8] 5,10-Dimethyldibenzo[*b*,*e*]azinium is in IUPAC nomenclature of **1**.

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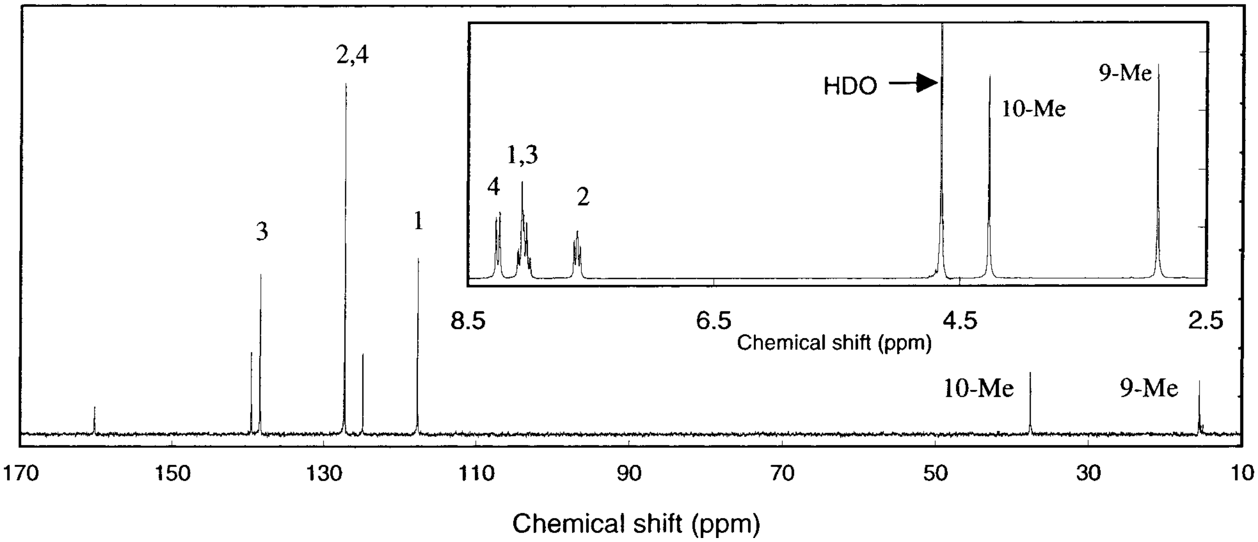
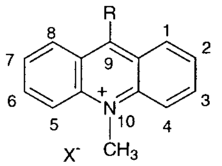
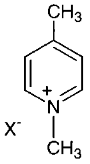


Figure 1. ^{13}C NMR spectrum of **1** in D_2O (1.0×10^{-1} M) at 25 °C. The insert shows the ^{1}H NMR spectrum of **1** in D_2O (1.0×10^{-1} M) at 25 °C. The positions of carbon atoms and protons in **1** are indicated by numbers beside the respective resonances. The resonances labeled 9-Me both in ^{13}C and ^{1}H NMR spectra disappeared upon conversion of **1** to **2**.

(211.13, calculated for $C_{15}H_{11}D_3N$ (**2**)) in the positive ion, while that of the starting compound is 208.1 (208.11, calculated for $C_{15}H_{14}N$ (**1**)). **2** was quite stable as such in solution and could be isolated from the solution by removing D_2O. On the other hand, **1** was quantitatively regenerated when the **2** formed was placed in H_2O, suggesting that the present exchange reaction is reversible.





1: R=CH_3, X=Cl, I, CH_3SO_4
2: R=CD_3, X=Cl, I, CH_3SO_4
3: R=CH_2CH_3, X=Cl

4: X= Cl, I

Kinetic measurements for the formation of **2** were taken in D_2O by means of ^{1}H NMR, integral values of the 9-methyl proton resonance (2.89 ppm in Figure 1) being utilized for estimating [**1**] or [**2**]. The conversion of **1** into **2** followed first-order kinetics with respect to the concentration of **1** over the temperature range studied (20−60 °C). The first-order plots derived therefrom give a straight line (Figure 2) with a slope or pseudo-first-order rate constant (k_{obs}) of 4.25×10^{-5} s^{-1} at 60 °C (half-value periods of reaction ($\tau_{1/2}$) = 4.5 h), 1.13×10^{-5} s^{-1} at 40 °C ($\tau_{1/2}$ = 17 h), and 1.83×10^{-6} s^{-1} at 20 °C ($\tau_{1/2}$ = 105 h). k_{obs}'s are independent of the initial concentration of **1** in the range 0.75×10^{-2} to 2.25×10^{-2} M. The experimentally obtained kinetic expression of the reaction rate thus can be written as eq 3. This suggests one

$$-d[\mathbf{1}]/dt = k_{obs}[\mathbf{1}] \quad \text{or} \quad k_{obs}t = \ln[\mathbf{1}]_0/[\mathbf{1}] \qquad (3)$$

molecule of **1** was concerned with the rate-determining step in the reaction. A plot of the reciprocal of the temperature (1/*T*) against first-order rate constant (k_{obs}), an Arrhenius plot, was found to be linear and the activation energy (E_a) as determined from the slope was 63.5 kJ mol^{-1}. This also exhibited that the exchange proceeds under rather mild conditions. The entropy and enthalpy of activation ($\Delta S^{\ddagger}$ and $\Delta H^{\ddagger}$) calculated from the activation energy were −145.7 J/K mol^{-1} and 61.0 kJ mol^{-1}, respectively.[1a] The negative entropy of activation predicts the formation of an activated complex as an intermediate in the transition state.

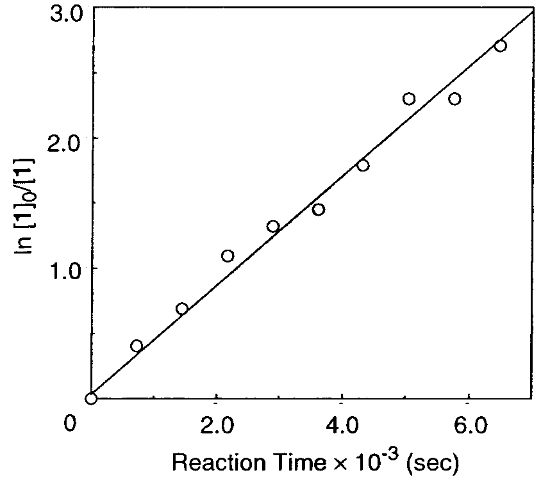


Figure 2. Analysis of the data according to first-order kinetics for the disappearance of **1** at 60 °C.

In marked contrast to **1** (X = Cl), none of the reference compounds including 9-methylacridine, 9-ethylacridinium chloride (**3**), and 1,4-dimethylpyridinium chloride (**4**) underwent the H−D exchange reaction in the methyl or methylene moieties under what were otherwise identical conditions to above. Neither the nature of the counteranions (Cl^-, I^-, or $CH_3SO_4^-$) in **1** nor the solvents (D_2O or CD_3OD) affected the rate of the H−D exchange reaction. In addition, photoirradiation with UV and visible light had no effect on the rate of the reaction.[9] This indicated that the H−D exchange reaction in the side chain occurs only at methyl groups directly substituted to the acridinium cation. The process was acceler-

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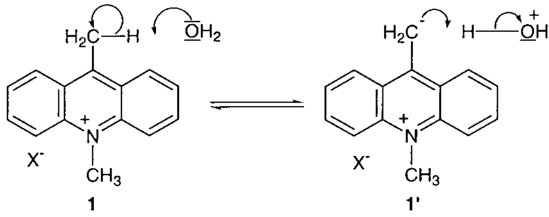
[9] Methyl protons in the radical cation of 10-methyl-9,10-dihydroacrdine are acting as an protic acid on photoirradiation, see: Manring, L. E.; Peter, K. S. *J. Am. Chem. Soc.* **1985**, *107*, 6452−6458.

ated by heating. In the presence of a radical scavenger ($Na_2S_2O_4$),[10] no improvement in reaction rate was observed indicating an ionic reaction mechanism. In addition to the kinetic and thermodynamic analyses one can predict that **1** in H_2O is in equilibrium (refer to eq 4) with its proton dissociated form (**1′**) where H_2O (or D_2O) is acting as a nucleophile, a base. As mentioned the negative $\Delta S^{\ddagger}$ suggests the formation of an activated complex (adduct), which presumably consists of an acridinium and water molecule in a transition state between **1** and **1′**. The proton dissociated form (**1′**) becomes predominant as the temperature of the solution rises. In particular the pH value of 3.9 at 20.0 °C and 3.7 at 46.0 °C in an aqueous solution of **1** (3.4×10^{-3} M) was observed whereas the pH of the pure water was about 6.9 at 20.0 °C in our experimental conditions under N_2 atmosphere. The pK_a of the protons was experimentally determined by means of the pH-dependent electronic spectral change;[11] therefore, **1** was dissolved in buffered aqueous solutions in the pH range 2−12 in order to measure the electronic spectra. **1**, however, causes decomposition of the acridinium skeleton giving a colorless solution under buffered basic conditions (pH < 7.5) and consequently the experimental pK_a value of **1** could not be determined by this method. If a base exists, **1** in H_2O is no longer equilibrated because the proton dissociated from **1** is captured by the base to irreversibly form **1′** or its unstable equivalent, 9-methyleneacridane (**5**, eq 5),[6] finally giving acridone. In fact the ^{1}H NMR spectrum of **1** in D_2O buffered by phosphate (pH 7.6, **1**:phosphate = 1:500) showed a resonance at 5.34 ppm (2H) assigned to the olefinic protons, CH_2= in **5**.[12] The pH of aqueous acetic acid at a concentration of 3.4×10^{-3} M are 3.59 at 20.0 °C.[13] Thus, the pK_a value of **1** is slightly higher than that of acetic acid (pK_a = 4.74).



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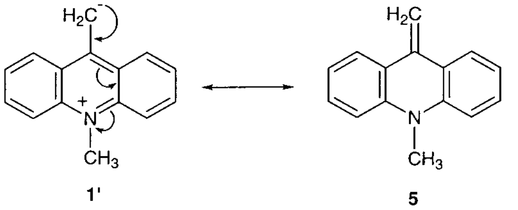

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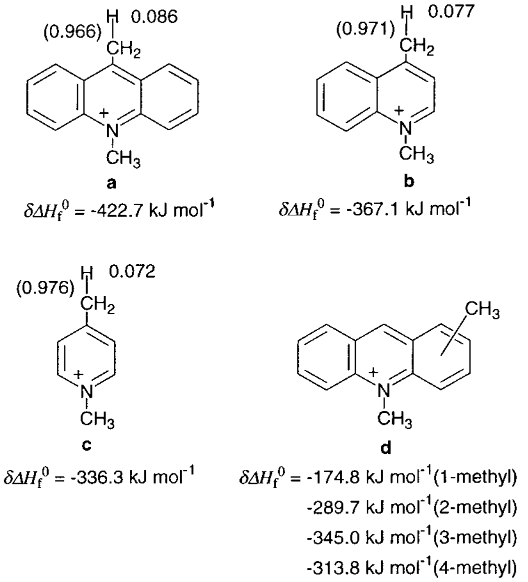

Figure 3. Model structures for the PM3 calculation. The numbers in the structures refer to the partial charges of the dissociating proton. The numbers in parentheses refer to the bond orders between the proton and an atom bound to the proton. The difference in heat of formation ($\delta\Delta H_f°$) was calculated from $\Delta H_f°$(undissociated form) + $\Delta H_f°(H_2O)$ − $\Delta H_f°$(dissociated form) − $\Delta H_f°(H_3O^+)$.

The K_a value of the dissociating proton is possible to predict from several factors including the partial charge on the proton, the bond order between the proton and an atom bound to the proton, and the difference in heat of formation ($\delta\Delta H_f°$: stabilization factor) between the proton undissocitatied and dissociated froms.[14,15] These three values were able to be calculated using the molecular orbital method. We adopted three model structures of N-heterocycle quarternary salts, 9-methylacridinium (**a**), 4-methylquinolinium (**b**), 4-picolinium (**c**), and their forms with one dissociated methyl proton (structures are not shown in Figure 3), to calculate the three factors mentioned above (Figure 3). PM3 semiempirical calculation in water by means of a conductor-like screening model (COSMO)[16] was utilized since PM3 simulates the experimentally determined acidity in aromatic compounds well and COSMO models describe the effect of the dielectric constant of the solvent upon the electron density of a solute molecule. Although a significant difference could not be perceived in their partial charges and bond orders, **a** exhibits the largest negative $\delta\Delta H_f°$ (−422.7 kJ mol^{-1}) indicating that among **a**, **b**, and **c**, **a** is most stabilized when one of the methyl protons is dissociated (Figure 3). In other words the methyl protons in **a** have a tendency to dissociate more easily than those in **b** and **c** and this is also substantiated by the experimentally obtained facts. The largest stabilizing factor observed in **1** upon proton dissociation might be derived from the wider π area that facilitates delocalization of the anion generated in the 9-methyl group. We also adopted monomethyl-substituted acridinium salts as

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[10] An example of a radical reaction of 9-methylacridine, see: Rimmer, E. L.; Bailey, R. D.; Pennington, W. T.; Hanks, T. W. *J. Chem. Soc., Perkin Trans. 2* **1998**, 2557−2562.

[11] Shinkai, S.; Araki, K.; Shibata, J.; Tsugawa, D.; Manabe, O. *Chem. Lett.* **1989**, 931−934.

[12] **5** is quite unstable at room temperature and undergoes facile self-sensitized photooxidation to afford 10-methylacridone (**7**) and also quarternarization with water to form **1** (X = OH), see: Suzuki, N.; Kato, M.; Izawa, Y. *Chem. Ind.* **1981**, 775−776, ref 3b, and ref 3c. 5-Methyl-10-methylene-5,10-dihydrodibenzo[*b*,*e*]azine is in IUPAC nomenclature of **5**.

[13] *Merck Index*, 12th ed.; 1996. The index exhibited the pH values of aqueous acetic acid; thus, 2.4 (1.0 M), 2.9 (0.1 M), and 3.4 (0.01 M).

[14] (a) Karman, R.; Huang, T.-S. L.; Fry, J. L. *J. Comput. Chem.* **1989**, *11*, 1009−1016. (b)Voets, R.; François, J.-P.; Martin, J. M. L.; Mullens, J.; Yperman, J.; Poucke, L. C. Van *J. Comput. Chem.* **1989**, *10*, 449−467. (c) Gilliom, R. D.; Beck, J.-P.; Purcell, W. P. *J. Comput. Chem.* **1985**, *6*, 437−440.

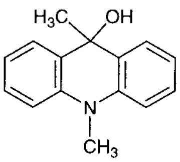
[15] The $\delta\Delta H_f°$ value between **1** and **1′** was represented by the following expression; thus, $\delta\Delta H_f° = \Delta H_f°(\mathbf{1'}) + \Delta H_f°(H_3O^+) - (\Delta H_f°(\mathbf{1}) + \Delta H_f°(H_2O))$.

[16] Klamt, A.; Schüürmann, G. *J. Chem. Soc., Perkin Trans. 2* **1993**, 799−805.

models where substitution was in the 1 to 5 positions (**d** in Figure 3). As in the models above, **a** is most stabilized out of the **a** and four **d** structures by dissociation of one of the methyl protons. This calculation strongly suggests that the unique reactivity should only appear in the 9-methyl substituent in acridinium. The 9-ethyl-10-methylacridinium cation is greatly stabilized upon dissociation of a benzyl proton ($\delta\Delta H_f^\circ = -471.0$ kJ mol^{-1}) and this is marked contrast with the experimental fact that the H−D exchange at the benzyl position in **3** did not take place. Presumably because the benzyl protons neighboring CH_3 and acridinium in **3** are sterically hindered as compared with the benzyl protons adjoining H and acridinium in **1**, the H_2O molecule cannot effectively approach the benzyl position in **3**, consequently preventing the formation of the **3**·H_2O complex as an intermediate. In particular the COMSO model cannot simulate electronic interactions, such as weak bond formation, between the solvent and solute, but only reflects the dielectric constant of the solvent.

1 could also be regarded as a monosubstituted methane and thus a comparison of the acidity of **1** ($pK_a = \sim 5$) with those for other methane derivatives is crucial. Because of the electronic structural analogy of the nitro group involving a positive charge on the nitrogen atom in a resonance form with N^+ in **1**, we have adopted the alkylmethanes as a reference; nitromethane and nitroethane possess pK_a values of 10.2 and 8.6 in H_2O,[17] and 17.2 and 16.7 in dimethyl sulfoxide (DMSO),[18] while methane itself has a value of ~56 in DMSO.[19] This indicates that the acridinium cation is a substituent which gives a great deal of acidic strength to methane upon substitution, although the ionic dissociation of acid in H_2O is enormously favored (7−8 pK units) over that in DMSO. Toluene and 9-methylanthracene as aromatic monosubstituted methanes exhibited pK_a values of ca. 43 and 31 in DMSO, respectively.[20] These substantiate the contribution of the positively charged nitrogen atom as well as the wider π area to the anion stabilization.[21]

9-Methyleneacridane (**5**: pseudobase), anhydrobase (**6**), and acridone (**7**) were formed when **1** reacted with the aqueous base and exhibited characteristic absorption bands in the visible region as well as NMR spectral changes.[6,22] ^{13}C NMR spectra of **1** in the temperature range 20−60 °C in D_2O showed none of the resonances corresponding to olefinic carbons, C−OH, and C═O but a remarkable electronic spectrum change. This clarifies that neither **5**, **6**, nor **7** were formed even as intermediates during the course of the reaction and also that the present reaction process of **1** in H_2O occurs in a completely different manner from that of **1** in basic H_2O.[23]



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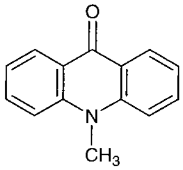

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In this report we have demonstrated that a methyl group in 9-methylacridinium (**1**) in D_2O undergoes facile H−D exchange reaction to give **2** quantitatively. The exchange process is derived from the equilibrium between **1** and **1′** in water. Of particular importance in the present reaction is that the methyl protons in **1** show unusual acidity. Thus 9-methylacridinium (**1**) functions as a remarkably strong electrophile, helping water molecules to act as a Brönsted base affording H_3O^+ and, in other words, the acridinium cation is a substituent that gives a great deal of acidity to methane upon direct substitution. The pK_a value of **1** is almost the same as that in acetic acid. Therefore the acidity exhibited by the methyl group in **1** is quite strong and unique. It has much to offer as a new organic protic acid useful for organic reactions and as a system exhibiting intermolecular interaction between **1** and biomolecules including DNA.

Experimental Section

Mass spectra were conducted on a Perseptive Voyager RP MALDI-tof spectrometer with or without a matrix (α-cyano-4-hydroxycinnamic acid). ^1H and ^{13}C NMR spectra were recorded on JEOL EX-270 and JEOL AL-300 spectrometers. $^1H-^{13}C$ COSY spectra were taken with a HMQC pulse sequence using the magnetic field gradient method. Electronic absorption spectra were recorded with a Beckman DU-7500 spectrophotometer. Photoirradiation was carried out with a HAMAMATSU Photo Cure 200 (Xe lamp) with or without a Shimadzu SPG-100S monochromator. The pH was measured on a HORIBA F-23 pH meter. Water utilized was purified by ion exchange, distillation, and fine-filtration.

9-Methylacridine was prepared according to the literature.[24] 9-Ethylacridine was also afforded by an identical procedure using propionic acid and diphenylamine as starting materials.

9,10-Dimethylacridinium (**1**)[6a,25] and 9-ethyl-10-methylacridinium (**3**)[6b] were synthesized from 9-methylacridine and 9-ethylacridine according to the literature. **1** (X = CH_3SO_4) was obtained by the reaction of 9-methylacridine with dimethylsulfuric acid.[26] 1,4-Methylpyridinium (**4**) (X = Cl) was synthesized according to the literature (2.9 g, 94.9%).[27]

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(17) Bordwell, F. G. *Acc. Chem. Res.* **1988**, *21*, 456−463.

(18) Matthews, W. S.; Bares, J. E.; Bartmess, J. E.; Bordwell, F. G.; Cornforth, F. J.; Drucker, G. E.; Margolin, Z.; McCallum, R. J.; McCollum, G. J.; Vanier, N. R. *J. Am. Chem. Soc.* **1975**, *97*, 7006−7014.

(19) Bordwell, F. G.; Zhao, Y. *J. Org. Chem.* **1995**, *60*, 6348−6352.

(20) Bordwell, F. G.; Harrelson, J. A. Jr.; Satish, A. V. *J. Org. Chem.* **1995**, *54*, 3101−3105.

(21) A referee of this article pointed out 9-methyl-10-nitroanthracene shows a pK_a of 13.2 in DMSO. This means that this molecule would be expected to show a similar pK_a value to that of **1** if dissolved in water. In fact the $\delta\Delta H_f^\circ$ values of these two molecules are almost identical, $\delta\Delta H_f^\circ$ of 9-methyl-10-nitroanthracene being −405.06 kJ mol^{-1}. Thus, the anthracene ring ($\delta\Delta H_f^\circ = -315.46$ kJ mol^{-1}) stabilized the benzylic carbanion by a pK unit of ca. 25 and the additional para N^+ in anthracene stabilizes the carbanion by another ca. 17 pK units.

(22) Isolation of **5**, see reference 12.

(23) According to the mechanism for reaction of **1** and an aqueous base[6,12] the following equilibrium mechanism of **1** (X = Cl) proton dissociation in neutral conditions could be also described. Thus, nucleophilic attack by H_2O on **1** (X = Cl) forms **6** and HCl, followed by **1** (X = OH). The strong basic OH^- counteranion in **1** (X = OH) abstracts a proton from the 9-methyl group to give **1′** and H_3O^+. However, nucleophilic attack by neutral H_2O on a neutral salt of **1** (X = Cl) to afford a strong acid, HCl, and a strong base of **1** (X = OH) is not reasonably to be expected. Furthermore, if HCl was evolved, the pH of the aqueous solution should be lowered more than indicated by the experimentally observed pH (pH = 3.9). In fact aqueous HCl at a concentration of 3.4×10^{-3} M exhibits a pH of 2.95 at 25 °C.

(24) Tsuge, O.; Nishinohara, M.; Tashiro, M. *Bull. Chem. Soc. Jpn.* **1963**, *36*, 1477−1485.

(25) Mooser, G.; Schulman, H.; Sigman, D. S. *Biochemistry* **1972**, *11*, 1595−1602.

(26) Bahr, N.; Güller, R.; Reymond, J.-L.; Lerner, R. A. *J. Am. Chem. Soc.* **1996**, *118*, 3550−3555.

(27) Minchi, M. J.; Shah, S. S. *J. Chem. Edu.* **1977**, *54*, 709.

Reaction of 1 with D_2O. Kinetic measurements of the deuteration of the methyl protons in **1** were carried out as follows: a D_2O (0.6 mL) solution of **1** (1.85×10^{-2} M) in a NMR test tube was placed into an NMR probe equipped with a variable temperature control system. The temperature of the reaction was regulated to a precision of ± 0.5 °C. The test tube was thermostated at 60, 40, and 20 °C. The progress of the reaction was monitored every hour by measuring the ^{1}H NMR spectrum, accumulation of one spectrum requiring 1 min. The concentration of **1** or **2** was determined by integration of the 9-methyl resonance (2.89 ppm). Pseudo-first-order rate constants (k_{obs}) were obtained from slopes of plots of $\ln[\mathbf{1}]_0/[\mathbf{1}]$, i.e., $\ln(I_0/I)$, vs t, where I_0 and I were the integration values at 2.89 ppm. Kinetic measurements were carried out similarly on solutions of **1** in the concentration range 0.75×10^{-2} to 2.25×10^{-2} M. Similar time-course experiments under different temperatures were also carried out with a spectrophotometer to measure electronic spectra in the UV−visible region.

2 was isolated from the NMR sample tube by removal of D_2O after the H−D reaction had been completed. The yield was almost quantitative, 2.3 mg of **2** being recovered from 2.3 mg of **1**. TLC (SiO_2, $CHCl_3$): $R_f = 0.45$. ^{1}H NMR (300 MHz, D_2O): δ 8.26 (d, 2H, $J = 8.8$ Hz), 8.07 (d, 2H, $J = 9.0$ Hz), 8.02 (dd, 2H, $J = 8.8, 9.0$ Hz), 7.61 (dd, 2H, $J = 8.8, 9.0$ Hz), 4.26 (s, 3H) ppm. ^{13}C NMR (67.5 MHz, D_2O): δ 160.2, 139.6, 138.4, 127.3, 124.9, 117.7, 37.6 ppm MS (MALDI-tof), calcd for $C_{15}H_{14}N$ 211.13, found 211.1.

1 was also quantitatively regenerated by stirring a H_2O (1.0 mL) solution of 2 (2.0 mg) for 4 h.

Molecular Orbital Method. CAChe (Oxford Molecular) Molecular Mechanics (MM) and MOPAC were utilized. Before calculating the partial charge, bond order, and heat of formation ($\delta\Delta H_f°$), the geometries of the model structures adopted were optimized by mean of MM and MOPAC. MM2 was used as the force field for MM calculation. PM3 was utilized as the MOPAC parameter.

Photo Irradiation of 1. An aqueous solution of **1** (7.0×10^{-5} M) in a sealed 1-cm quartz cell and a D_2O solution of **1** (1.85×10^{-2} M) in a NMR test tube were thermostated at 25 °C with a water circulator. UV light at 254 or 350 nm, where **1** exhibits absorption, or white light irradiated the samples for 2−8 h. Electronic and ^{1}H NMR spectra were measured before and after photoirradiation.

pH Measurement. An aqueous solution of **1**, phenol, acetic acid, and HCl (3.4×10^{-3} M) was transferred to a sealed test tube equipped with a pH electrode under a N_2 atmosphere. The tube was thermostated at the temperature required using a water circulator, and the pH was measured.

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Supporting Information Available: UV−vis spectra of **1** before (25 °C) and during (60 °C) the H−D exchange reaction. ^{1}H and ^{13}C NMR spectra of **2** as an indicator of purity. Experimental procedure for the preparation of 9-methylacridine, 9-ethylacridine, 9,10-dimethylacridinium chloride (**1**), and 9-ethyl-10-methylacridinium chloride (**3**) and their characterization data. This material is available free of charge via the Internet at http://pubs.acs.org.

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