# Charged and Betainic Nucleobases. On Syntheses and Properties of First Mesomeric Uracilylbetaines, Uracilates, and Novel Uracilium Salts

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Nucleophilic heteroaromatic substitution of DMAP and 1-methylimidazole on the 6-chlorouracil **1** gave the uracilyl hetarenium salts **2** and **4**, respectively. Depending on the nucleophile, the substitution could be catalyzed by interception of the leaving group either with sodium tetraphenylborate or with antimony pentachloride in a non-coordinating solvent. Catalysis with other Lewis acids failed due to the formation of stable coordination compounds **3**. Surprisingly, *Finkelstein*-type reaction conditions provide an efficient approach to the imidazolium iodide **4**. Depending on the reaction conditions, treatment of the 6-chlorouracil **5** with DMAP resulted in the formation of the pyridinium uracilate **6**, the uracilyl pyridinium chloride **7a**, and the novel pyridinium-uracilate **8** which is a cross-conjugated mesomeric betaine (CCMB). Alkylation of the mesomeric betaine **8** with 1,2-dichloroethane/$SbCl_5$ gave the biscation **9**. Analogously, 1-methylimidazole or 2,4,6-trimethylpyridine as nucleophiles formed the salts **10a** and **12**, respectively, and the imidazolium-uracilate **11**. This is the first representative of a cross-conjugated heterocyclic mesomeric betaine isoconjugate with odd nonalternant hydrocarbon anions. PM3 calculations were performed on the cation **2** and on the mesomeric betaine **8**. Whereas the cation **2** was found to have an essentially perpendicular torsional angle Φ around the $CN^+$ bond linking the uracil and the pyridinium units, the mesomeric betaine **8** adopts a nearly planar conformation, thus allowing stabilizing $\pi$ interactions. Accordingly, upon rotation about the $CN^+$ bond, the expected maxima were found at essentially perpendicular conformations. Due to the balance between three effects which act in opposite directions, (i) stabilizing p overlap, (ii) N(8)/2-H attractive interaction, and (iii) steric repulsion between 6-H and 12-H, two additional small minima were surprisingly found at Φ = 36.6° and 219.3°. The charge separation in the ground state of the mesomeric betaine **11**, and the ground-state ion-pair complexes of the hetarenium iodides **2d**, **4**, **7c**, and **10b** were confirmed by the effect of negative solvatochromism.

The biological role of mesomeric betaines as modified ribonucleosides was not recognized before 1961 when the betainic 7-methylguanosine ($m^7G$) was found to be a building element of tRNA.[1,2] In the course of intense studies which revealed the profound influence of this dipolar residue upon both the processing and function of nucleic acids, it was further identified as the 5′-terminal nucleotide of eucaryotic mRNA, stabilizing the molecule and facilitating binding of ribosomes prior to initiation of translation.[3] Later, dimethylguanosine ($m^{2,7}G$) and trimethylguanosine ($m^{2,2,7}G$) were isolated as additional natural betainic nucleosides.[4] Although much work has been concentrated upon the search for novel prodrug derivatives of modified pyrimidine nucleobases[5] including 5-fluorouracil (5-FU), widely used as an antitumor agent,[6] not much interest has been developed in the synthesis of new highly dipolar pyrimidines as potential biologically active compounds. However, the activities of known positively charged and betainic heterocyclic systems that are hetarenium-substituted cover the range from antitrichomonal,[7] antileishmanial,[8] amebicidal,[9] and antiprotozoal[10] agents, acetylcholin-esterase reactivators,[11] and herbicides[12] to semiconductors.[13] Furthermore, the

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chemistry and widespread use of uracils as active principles have recently been reviewed.[14]

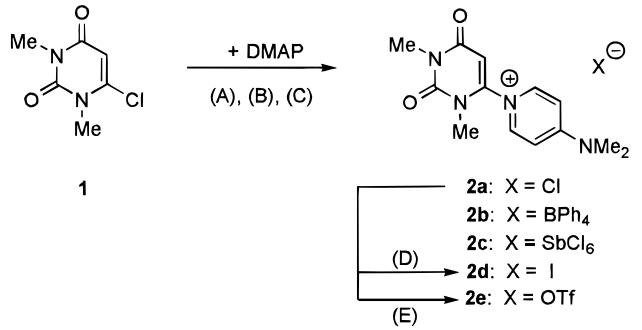
As part of a program on the syntheses and properties of cationic and polycationic heteroaromatics,[15] we aimed at the preparation of representatives of hitherto unknown anionic, cationic, and betainic uracil derivatives. This publication describes the reactions of 6-chlorouracils with heteroaromatics. It was of particular interest to evaluate the scope and limitations of the possible variations of the substitution pattern of the chlorouracil, the nucleophile, the anion, and the reaction conditions. Such a series of reactions provided several new uracilyl hetarenium salts and a new class of mesomeric betaine anticipated to have interesting spectroscopical and chemical properties. By the choice of anion, we could vary the solubility of the resulting modified nucleobases between the two extremes, highly water-soluble and lipophilic. Furthermore, we performed semiempirical calculations on representative compounds.

## Results and Discussion

**Syntheses.** Hitherto, only a limited number of synthetic methods leading to *conjugated* hetarenium compounds have been reported, including the ring transformation of pyrylium salts with amines,[16] *Ortoleva*−*King*-type reactions,[17] trimethylsilyl triflate-assisted substitutions,[18] and direct reaction with highly nucleophilic heteroaromatics on vinyl chloride structures.[19] However, attempts to apply the reported methods to uracils were completely unsuccessful. As reported in a preliminary publication,[15a] we could surprisingly accomplish the direct substitution of 6-chloro-2,4(1*H*,3*H*)-pyrimidinedione (**1**) with 4-(dimethylamino)pyridine (DMAP) in boiling 1,2-dichlorobenzene ($E_T^N = 0.225$),[20] whereas many other solvents failed. This is illustrating the considerable sensitivity of such reactions toward solvent effects.[19] Thus, 4-(dimethylamino)-1-[1,3-dimethyl-2,4-dioxo-1,2,3,4-tetrahydropyrimidin-6-yl]pyridinium chloride (**2a**) was formed as a highly water-soluble,[21] grey precipitate (Scheme 1).

Catalysis of the substitution was accomplished by different strategies. First, we found that interception of the leaving group by the presence of equimolar amounts of the nonnucleophilic sodium tetraphenylborate (NaTPB) in ethyl acetate is a mild and efficient method to synthesize the uracilylpyridinium tetraphenylborate **2b** and sodium chloride as an easily separable byproduct. The presence of water results in the formation of insoluble pyridinium tetraphenylborate coordination compounds.[22]

**Scheme 1**[a]




[a] Reagents and conditions: (A) method A, 1,2-dichlorobenzene, reflux;[15a] (B) method B, $NaBPh_4$, ethyl acetate, reflux; (C) method C, 1,2-dichloroethane, antimony pentachloride, reflux; (D) sodium iodide, acetone, reflux; (E) TMSOTf, $CH_2Cl_2$, reflux.

Second, several Lewis acids were added to the reaction mixture to exert an electrophilic pull on the departing chloride. Moreover, in recent years there has been immense interest in investigating the possible mechanisms of nucleophilic attack on carbon−carbon double bonds of both substituted alkenes[23] and heterocyclic systems.[24] If the substitution of the chloride **1** with heteroaromatics proceeded *via* the $Ad_N$-E mechanism, which is a special case of dipolar transition state reaction, the primary attack at C-6 should be considerably facilitated by the complexation of the Lewis acids at O(4) of the uracil moiety, which is under physiological conditions, in addition to O(2), the methylation site in pyrimidine nucleobases subjected to attack by carcinogenic alkylating agents.[25] However, *ab initio* calculations[26] and experimental data[27] lend strong support to O(4) as coordination site of metals. In order to avoid competing reactions such as complexation of the Lewis acid by the nucleophile or its conversion into perhetarenium compounds,[28] and as no reports on complexes of 6-chlorouracils exist, we examined the interaction of hard as well as soft Lewis acids with uracil **1**. Addition of antimony pentachloride or aluminum chloride to a solution of **1** resulted in instant formation of precipitates, whereas the crystallization of the boron trifluoride and zinc chloride complexes required concentration of the reaction mixture *in vacuo* and cooling. Indeed, analytical and spectroscopical data indicated the unambiguous formation of 1:1 complexes **3a**−**d**, which were quite stable against air and moisture (Scheme 2).

However, only the addition of antimony pentachloride, intermediate between hard and soft acids, to a mixture of the 6-chloropyrimidine and DMAP in the non-coordinating solvent 1,2-dichloroethane resulted in the spontaneous formation of the intense yellow-colored hexachlo-

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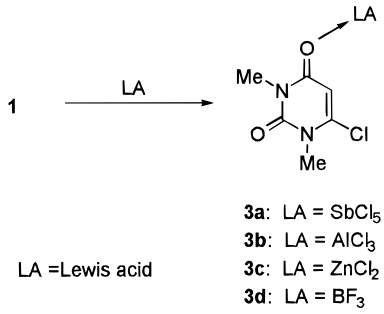
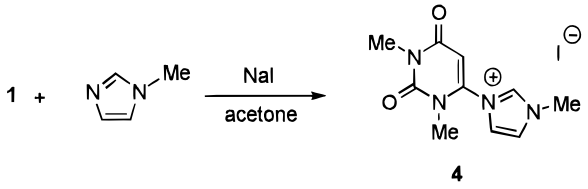
**Scheme 2**




**Scheme 3**




roantimonate **2c** in 85% yield. Despite intense efforts, all other Lewis acids failed due to the formation of nearly insoluble, nonstoichiometric DMAP complexes, as evidenced by NMR measurements.

The iodide **2d** was readily obtained starting from **2a** by anion exchange with NaI in acetone. No reaction was observed by addition of an equimolar mixture of DMAP and trimethylsilyl trifluoromethanesulfonate (TMSOTf) in dichloromethane to the 6-chloropyrimidine, although the reaction should be driven by the loss of chlorotrimethylsilane from solution, resulting in the irreversible interception of the departing chloride. The desired stable, nonhygroscopic triflate **2e**, however, was formed upon anion exchange of **2a** using TMSOTf in dichloromethane (Scheme 1).

These reaction conditions could not easily be transferred to 1-methylimidazole as the nucleophile, because either high reaction temperatures or treatment with antimony pentachloride caused decomposition of the starting material. However, when *Finkelstein*-type reaction conditions[29] (taking advantage of the fact that sodium iodide, but not the chloride, is soluble in acetone) were applied, the iodide **4** was surprisingly formed under mild conditions and in high yield as a stable brownish solid (Scheme 3). Unfortunately, the TPB derivative could not be obtained.

The use of pyridine and substituted pyridines such as picoline or collidine as nucleophiles for an analogous series of reactions was impractical because of the degradation of the heteroaromatic ring system. Thus, either an inseparable mixture of reaction products was obtained or large amounts of the starting material could be recovered.

Exchanging the dimethyluracil derivative **1** with the corresponding 6-chloro-3-methyl-2,4(1*H*,3*H*)-pyrimidinedione (**5**) made possible the formation of hitherto unknown salts and mesomeric uracilylbetaines. Due to the acidic properties of this uracil derivative [p$K_{a1}$($H_2O$) = 5.84], the results of the nucleophilic substitution with heteroaromatics showed a strong dependence on the nucleophile itself and on the reaction conditions used. Thus, acid−base reaction to give the simple 4-(dimethylamino)-

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**Table 1. Selected Spectral Data of the Uracilate 6, the Cations 7 and 9, and the Mesomeric Betaine 8 in Comparison with the 6-Chlorouracil 5 and DMAP**

| | $^1$H NMR[a] | | | $^{13}$C NMR[a] | IR[b] | UV[c] |
|---|---|---|---|---|---|---|
| | 5-H/12-H[d] | 2-H[d,e] | 3-H[d,e] | C-5/C-12[d] | $\nu$($C_2$=O) | $\lambda_{max}$ |
| **5** | 5.89 | | | 99.2 | 1733.9 | 255.40 |
| DMAP | | 8.10 | 6.57 | | | 258.20[g] |
| **6** | 5.41 | 8.19 | 6.85 | 94.6 | 1644.8[f] | 277.00 |
| **7a** | 6.12 | 8.43 | 7.18 | 93.7 | 1718.5 | 311.80 |
| **7b** | 6.17 | 8.38 | 7.18 | 94.6 | 1716.3 | 309.60 |
| **7c** | 5.96 | 8.58 | 7.13 | 89.7 | 1736.6 | 312.70[h] |
| **9** | 6.16 | 8.39 | 7.17 | 94.7 | 1728.7 | 311.70 |
| **8** | 5.70 | 8.81 | 7.06 | 82.6 | 1652.6[f] | 303.30 |

[a] In ppm; solvent, DMSO-$d_6$. [b] KBr pellets; in cm$^{-1}$. [c] In nm; solvent, dichloromethane. [d] For numbering of **2** and **8**, see Table 2. [e] $\delta$H corresponds to the center of the dublet. [f] Center of gravity of a broad absorption. [g] *Cf.* ref 36. [h] Complete conversion into **8** occurred within 45 min.

pyridinium 6-chloro-3-methyl-2,4(1*H*,3*H*)-pyrimidinedionate (**6**), which crystallized well as great yellow needles, was accomplished even if the starting materials **5** and DMAP were mixed in nonstoichiometric amounts. The neutralization could be monitored by NMR spectroscopy. Thus, in agreement with the assigned structure, the resonances of the uracil shifted upfield [e.g. $\Delta\delta$(5-H) = −0.48 ppm], whereas the hetarene signals moved downfield during salt formation [e.g. $\Delta\delta(3\text{-H})_{DMAP}$ = +0.28 ppm] (Table 1). Upon subsequent addition of Tfa-*d* to the solution, the uncharged uracil reconstituted [e.g. $\Delta\delta$-(5-H) = +0.48 ppm], whereas, as expected, all resonances of the hetarenium remained virtually unchanged.[30] Furthermore, the $C_2$=O valence band at 1733.9 cm$^{-1}$ moved typically to lower frequencies upon neutralization [$\Delta\nu$ = 70−80 cm$^{-1}$],[31] whereas the $\nu$(NH) band of the uracil at 3089.2 cm$^{-1}$ was replaced by the NH absorption of 4-(dimethylamino)pyridinium at 3435.6 cm$^{-1}$. In EIMS the fragmentation schemes of both the DMAP (*m*/*z* = 122; 83%) and of the uracil (*m*/*z* = 160; 70%) were found. Furthermore, the combustion analysis was consistent with the formation of a 1:1 compound.

In contrast, due to the lower basicity of either 1-methylimidazole [p$K_a$ = 7.20] or 2,4,6-trimethylpyridine [p$K_a$ = 7.63], no salt formation occurred with **5**, as evidenced by NMR[30] and IR spectroscopy (Scheme 4).

Treatment of the 6-chloropyrimidine with stoichiometric amounts of DMAP in boiling 1,2-dichlorobenzene resulted in the formation of the water-soluble uracilyl pyridinium salt **7a** which could be subjected, for synthetic verification of the chloride, to an anion exchange reaction with TMSOTf in dichloromethane to form the nonhygroscopic, pure triflate **7b**.

Surprisingly, in the presence of a 2-fold excess of DMAP the mesomeric betaine **8** was formed in high yield, which is, to the best of our knowledge, the first known mesomeric betaine of uracil. According to the classification by *Ollis*, *Stanforth*, and *Ramsden*,[32] compound **8** represents a member of the class of cross-conjugated mesomeric betaines (CCMB) which are isoconjugate with

(30) As 1-methylimidazole formed no salt applying these reaction conditions, the differences in chemical shifts which are due to changes in the static dielectric constant of the solvent DMSO-$d_6$ on addition of the base could be determined to $\Delta\delta$(5-H) = +0.10 ppm. On addition of Tfa-*d*, the imidazole signals shifted to lower field (from 7.00, 7.19, 7.80 to 7.66, 7.70, 9.08 ppm), whereas the uracil resonances were unchanged.

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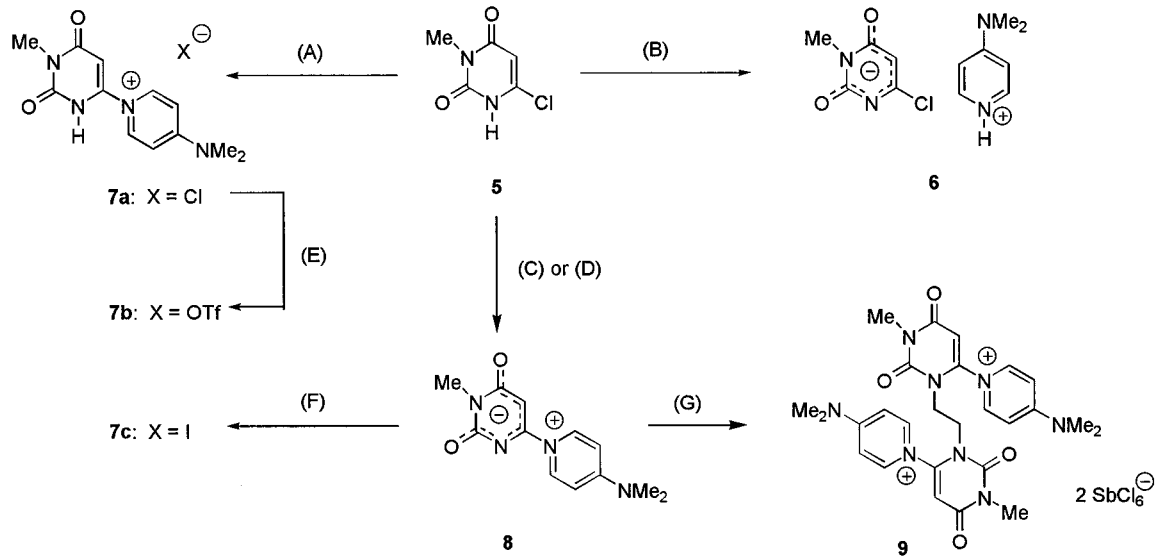
**Scheme 4**[a]




[a] Reagents and conditions: (A) DMAP, 1,2-dichlorobenzene, reflux; (B) DMAP, ethyl acetate; (C) 2.5 equiv of DMAP, ethyl acetate, reflux; (D) DMAP, $NaBPh_4$, anhydrous MeCN, reflux; (E) TMSOTf, $CH_2Cl_2$, rt; (F) HI, acetone, rt; (G) 1,2-dichloroethane, 2 equiv of $SbCl_5$, rt.

even alternant hydrocarbon dianions. The application of the valence bond approach demonstrates that the positive and the negative charges are restricted to separate parts of the $\pi$-electron system, and this was indeed reflected in the spectroscopic features (Table 1).

Very surprisingly, when substitution in the presence of NaTPB was attempted, formation of the mesomeric betaine **8** occurred, and this could scarcely be anticipated. Despite intense efforts, no traces of the desired TPB salt could be detected in NMR spectroscopy.

An emulsion of **8** in acetone, on addition of aqueous hydrogen iodide, converted the mesomeric betaine to the iodide **7c** in high yield, which is an additional proof of structure. However, decomposition occurred even if the substance was stored under argon. As evidenced by UV spectroscopy, complete conversion of the dichloromethane solution of **7c** into **8** occurred within 45 min.

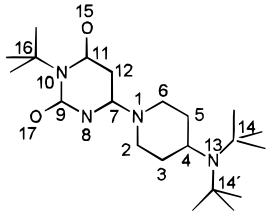
Similarly, alkylation of the mesomeric betaine **8** was accomplished with 1,2-dichloroethane in the presence of antimony pentachloride to afford the symmetrical biscation **9** as bis-hexachloroantimonate which is intense yellow in color. In accordance with UV spectroscopy literature values,[33] the $s^0$ configuration of the pentavalent antimony in $SbCl_6^-$ causes a $t_{1u}(\pi)-a_{1g}$–LMCT transition which is observable as a shoulder at 270 nm. The structure was further confirmed by the characteristic spectral features of the cationic species (Table 1) plus the resonances of the methylene group in NMR spectroscopy.

Changing the solvent to dichloromethane resulted in the formation of nonstoichiometric $SbCl_5$ complexes. Due to the plethora of potential binding sites [O(15), O(17), N(8), $NMe_2$; for numbering, see Table 2][27] and due to the insolubility in common organic solvents, the structures of these coordination compounds could not be unambiguously elucidated.

Under analogous reaction conditions, 1-methylimidazole as the heteroaromatic nucleophile formed the water-soluble 1-(2,4-dioxopyrimidin-6-yl)imidazolium chloride **10a** as a pure, well-defined compound. In accordance with the aforementioned 1,3-dimethyl series, trying to transform the chloride of **10a** with TMSOTf to the triflate led to progressive decomposition of the starting material (Scheme 5).

Similar to the reactions mentioned above, the imidazolium-uracilylate **11**, which is to our knowledge the first member of a new class of mesomeric betaine, was formed as a grey solid in the presence of stoichiometric amounts of either sodium TPB in MeCN or excess nucleophile or by heating the salt **10a** without solvent to 160 °C. Following the valence bond approach, the positive and negative charges are restricted to separate parts of the $\pi$-electron system as no common sites for the

**Table 2. Results of the Semiempirical Calculation (PM3) of the Cation 2 and of the Betaine 8**

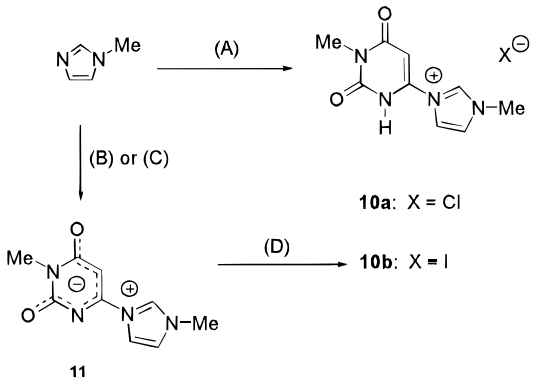


| | 2 | 8 |
|---|---|---|
| heat of formation $\Delta H_f$[a] | 517.27 | −28.26 |
| torsional angle $\Phi$[b] | 83.7° | 1.9° |
| ionization potential | 12.71 eV | 7.85 eV |
| charge distribution at | | |
| N(1) | +0.395 | +0.530 |
| C(2) | +0.290 | +0.335 |
| C(7) | −0.148 | −0.017 |
| N(8) | +0.054 | −0.389 |
| C(12) | −0.186 | −0.437 |
| O(15) | −0.293 | −0.405 |
| bond lengths [pm] | | |
| C(4)−N(13) | 136.83 | 140.97 |
| C(5)−C(6) | 137.13 | 137.96 |
| C(7)−N(1) | 146.67 | 147.25 |
| C(7)−N(8) | 142.66 | 134.74 |
| C(7)−C(12) | 135.03 | 137.31 |
| C(11)−O(15) | 121.61 | 122.89 |
| dipole moment[c] ($\Sigma$) | 13.238 | 16.380 |

[a] In kJ $mol^{-1}$ at 25 °C. [b] N(8)−C(7)−N(1)−C(6). [c] Reference 45.

(33) Lever, A. B. P. *Inorganic Electronic Spectroscopy*, 2nd ed.; Elsevier: Oxford, 1984.

**Scheme 5**[a]




[a] Reagents and conditions: (A) **5**, chlorobenzene, reflux; (B) **5**, $NaBPh_4$, anhydrous MeCN, reflux; (C) **5**, excess imidazole, acetone, reflux; (D) HI, acetone.

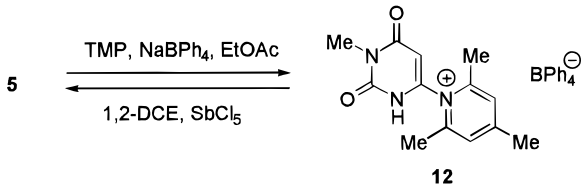
formal location in canonical forms of both positive and negative charges exist. So, the betaine **11** belongs to the class of cross-conjugated heterocyclic mesomeric betaines (CCMB), and this is also confirmed by the recognition of the characteristic dipole-type of this class of MB.[32] Furthermore, it is isoconjugate with odd nonalternant hydrocarbon anions and this category of CCMB, to the best of our knowledge, has been nonexistent until now.

Due to the charge separation in the ground state of the molecule, the cross-conjugated mesomeric betaine **11** exhibits a strong effect of negative solvatochromism.[34] As the zwitterionic ground state of the molecule is better stabilized by polar rather than by nonpolar solvents, the $\pi-\pi^*$ absorption, which is associated with an intramolecular charge transfer, shifts to shorter wavelengths with increasing solvent polarity. Thus, a solvent change from dichloromethane to methanol causes a hypsochromic shift of the UV maxima of *ca.* 19 nm [$\lambda_{max}$ = 323.17 nm ($CH_2Cl_2$; $E_T^N$ = 0.309); $\lambda_{max}$ = 315.20 (MeCN; $E_T^N$ = 0.460); $\lambda_{max}$ = 304.20 nm (MeOH, $E_T^N$ = 0.762)[20]].

A CCMB cation transformation could be achieved by suspending a sample of the betaine **11** in acetone and protonating at N(8) with HI. The resulting iodide **10b** was formed in very high yield, whereas neither methylation with MeI nor alkylation with 1,2-dichloroethane/antimony pentachloride could be accomplished.

The synthesis of the uracil-6-yl-2,4,6-trimethylpyridinium salt **12** required an *in-situ* replacement of the departing chloride by TPB, which resulted in the formation of **12** in fair yield. In contrast to the DMAP and the imidazole series mentioned above, neither the chloride nor the iodide could be obtained. Applying *Finkelstein*-type reaction conditions, the 6-chloropyrimidine was recovered quantitatively. Surprisingly, due to the chlorinating properties of antimony pentachloride, experiments to alkylate the uracilyl-2,4,6-trimethylpyridinium salt **12** at N(8) with 1,2-dichloroethane (1,2-DCE), aiming at the synthesis of a biscation such as **9**, resulted in the formation of the starting materials collidine and 6-chloropyrimidine **5**. Despite intense effords, the salt **12** could not be deprotonated to give a betaine. In accordance to the results of the PM3 calculation (Table 2), steric hindrance by the α-methyl groups might be the reason for this, compelling the system into a staggered conformation with a reduced p overlap between the pyridinium and uracilate segments (Scheme 6).

**Scheme 6**




TMP: 2,4,6-trimethylpyridine

**Spectroscopic Features.** The structure of the mesomeric betaines and the salts were unambiguously confirmed by all spectroscopical measurements. Characteristical features of the series of DMAP derivatives are depicted in Table 1. As predictable, the NMR signals of the C(12)-H group of the betainic structures **8** and **11** were found between the resonance frequency of the uracilate anion **6**, which was shifted considerably upfield relative to the starting uracil **5** [$\Delta\delta$($^1$H NMR) = −0.48 ppm], and the resonance frequencies of the corresponding cations **7**, **9**, and **10**, respectively, which were shifted downfield relative to **5** [$\Delta\delta$($^1$H NMR) = +0.07−0.28 ppm]. The calculated charge distribution on C-12 is in total agreement with these observations (Table 2). Addition of small amounts of Tfa-*d* to a DMSO-$d_6$ solution of the mesomeric betaine **8** and protonation at N(8), forming the salt **7b**, caused the corresponding downfield shift of 12-H, which is an additional proof of structure. No NH signals were observed in NMR spectroscopy of **8**. In contrast to *N*-acylammonium salts reported in the literature,[35] the spectra do not point at a hindered rotation on the NMR time scale about the hetarenium−*N*-uracilate bond.

In total agreement with the assigned structures, both the higher energy carbonyl absorption band of the salts **7**, **9**, and **12**, $\nu$($C_9$=O) at 1712.6−1736.6 cm$^{-1}$,[31] and of the combined $\nu$($C_{11}$=O) + $\nu$(C=C) absorption at 1673.5−1683.7 cm$^{-1}$ were moved to higher frequencies compared with those of the betaines **8** and **11**, which had a strong $\nu$($C_9$=O) + $\nu$($C_{11}$=O) + $\nu$(C=C) absorption with the center of gravity at 1652.6 and 1645.1 cm$^{-1}$. This observation indicates a diminished bond order due to the negative charge located in the betainic pyrimidine moiety. In the electronic spectra, the anion formation of the 3-methyluracil **5** to the uracilate **6** was manifested by a typical bathochromic shift of the absorption maximum of 21.6 nm (Table 2).[36,37] Likewise, the direction of the spectral shift of the maxima exhibited by the 6-pyridinium-substituted uracils in passing from the cationic (**7**, **9**, **10**) to the betainic species (**8**, **11**) were also similar ($\Delta\lambda_{max}$ = −36.5 to −8.4 nm).

The iodides **2d**, **4**, **7c**, and **10c** form ground-state ion-pair complexes, the longest wavelengths of which correspond to an intramolecular transfer of an electron from the iodide to the pyridinium segment with annihilation of charge during the transition.[20] As a consequence, the CT transition causes different dipole moments of the ground and excited states so that, similar to the pyridinium iodides which were taken by *Kosower et al.* to

(34) Liptay, W. *Angew. Chem.* **1969**, *81*, 195; *Angew. Chem., Int. Ed. Engl.* **1969**, *8*, 177.

(35) (a) King, J. A., Jr.; Bryant, G. L., Jr. *J. Org. Chem.* **1992**, *57*, 5136. (b) King, J. A., Jr.; Bryant, J. L., Jr. *Synth. Commun.* **1994**, *24*, 1923.

(36) Upon cation formation, the UV absorption maxima of DMAP shift from 261.0 to 280.5 nm ($H_2O$): Essery, J. M. *J. Chem. Soc.* **1961**, 3939.

(37) Wempen, I.; Fox, J. J. *J. Am. Chem. Soc.* **1964**, *86*, 2474.

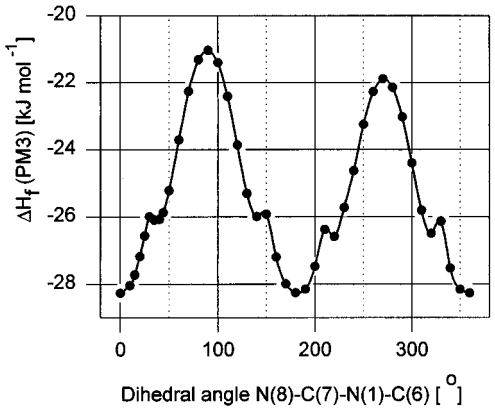



**Figure 1.** Conformational study of the mesomeric betaine **8**. Heat of formation $\Delta H_f$(PM3) *vs* dihedral angle Φ.

define the *Z* values as a measure of solvent polarity,[38] negative solvatochromism was observable. Thus, upon changing the solvent from $CH_2Cl_2$ [$E_T^N = 0.309$] to MeCN [$E_T^N = 0.460$] and MeOH [$E_T^N = 0.762$], the $\pi-\pi^*$ maxima of **7c** were shifted from 312.70 to 305.90 and 303.40 nm.

**Semiempirical Calculations.**[39] We carried out PM3 calculations[40] on the uracilium cation **2** and on the mesomeric betaine **8**. The geometries were totally optimized. On calculating the fully optimized ground-state geometry, we found a nearly perpendicular torsional angle Φ around the $N(1)^+-C(7)$ bond of **2**, linking the pyrimidine and the pyridine moiety (Φ = 83.7°). The heat of formation for the fully staggered, exactly perpendicular conformation of the uracilium cation **2** was calculated to be only 0.18 kJ above the totally optimized geometry we found. Obviously, the methyl group at N(8) causes this deviation from Φ = 90°. However, as the energetic difference is very small, the electronic characteristics of the cation are not influenced in a significant way.

In contrast, according to the PM3 calculation the mesomeric betaine **8** adopts an essentially planar conformation; the N(8)−C(7)−N(1)−C(6) angle Φ = 1.9° (*cf.* Figure 2). This conformation renders possible stabilizing interaction between the $\pi$ aromatic ring cloud of the pyridinium and the 2p orbital of C(7) of the uracil. It is not unexpected, then, that upon rotation about the $N(1)^+-C(7)$ bond, which is joining the two ring systems of the mesomeric betaine **8**, two maxima $\Delta H_f$(PM3) = −21.03 and −21.89 kJ mol$^{-1}$ at 89.2° and 270.9° are observed (Figure 1), because these geometries greatly reduce the overlap of the p orbitals and thus prevent a charge transfer from the anionic to the cationic part of the molecule.[42a] Interestingly, depending on the direction of rotation (+90° *vs* −90°) starting from the most stable, essentially planar ground state, two slightly different

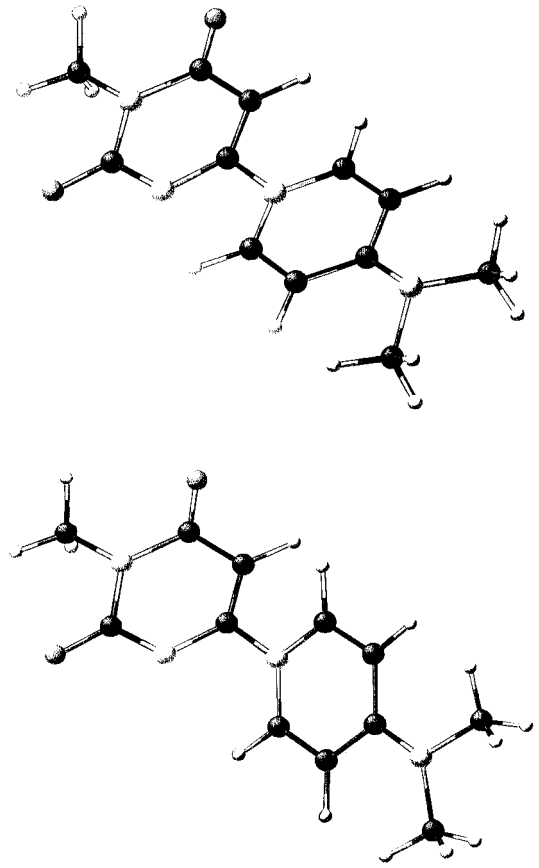


**Figure 2.** Conformational study of the mesomeric betaine **8**. Top: ground state, dihedral angle Φ = 1.9°. Bottom: conformation of the local minimum at 36.6°, which results from (i) the steric repulsion of 6-H and 12-H, (ii) the attractive interaction between 2-H and the N(8) lone pair, and (iii) stabilizing p overlap between the two rings.

transition states were determined, the difference in energy of which is $\Delta\Delta H_f$(PM3) = 0.86 kJ mol$^{-1}$. The higher barrier corresponds to the *syn* orientation of the lone pairs of the $NMe_2$ group and of N(8).

However, other factors influence the conformation. Steric repulsions destabilize the ground state, in which the interatomic distance between 6-H and 12-H is calculated to be 179.2 pm, whereas the "aromatic C-H/lone pair"[43] interaction between 2-H and N(8) is an attractive one. Accordingly, as a result of the balance between these competing attractive and repulsive interactions, at dihedral angles of 36.6° and 219.3° additional small local minima [$\Delta H_f$(PM3) = −26.11 and −26.60 kJ mol$^{-1}$, respectively] and corresponding maxima at 29.7° and 209.5° [−25.99 and −26.37 kJ mol$^{-1}$, respectively] were found. The calculated interatomic distance between 6-H and 12-H of 231.0 pm at Φ = 36.6° is in accordance with the 2-fold *van der Waals* radii $2r_H^{vdW}$ = 240 pm,[44] thus proving the beginning influence of steric interaction upon rotation to the planar geometry. Correspondingly,

(38) (a) Kosower, E. M. *An Introduction to Physical Organic Chemistry*; Wiley: New York, 1968; p 293. (b) Kosower, E. M. *J. Am. Chem. Soc.* **1958**, *80*, 3253.

(39) Calculations were carried out using MOPAC 6.0[41] on a Convex 3440. The structures were first optimized with the default gradient requirements and subsequently refined with the options EF DMAX = 0.05, GNORM = 0.1, SCFCRT = $1 \times 10^{-15}$; the cation **2** was calculated with the option CHARGE = +1. In the case of the mesomeric betaine **8**, we started the calculation of the ground state from both the planar and the staggered conformation in regard to both ring systems, to ensure that no hysteresis was affecting the results.

(40) Stewart, J. J. P. *J. Comput. Chem.* **1989**, *10*, 209.

(41) Stewart, J. J. P. *QCPE*, No. 455, Department of Chemistry, Bloomington, IN, 1989.

(42) (a) Bock, H.; Nick, S.; Näther, C.; Göbel, I.; John, A.; Kleine, M. *Liebigs Ann. Chem.* **1995**, *1*, 105. (b) Wittmann, E.; Ziegler, E.; Peters, K.; von Schnering, H. G. *Monatsh. Chem.* **1983**, *114*, 1983. (c) Franham, W. B.; Middleton, W. J.; Fultz, W. C.; Smart, B. E. *J. Am. Chem. Soc.* **1986**, *108*, 3125. (c) Bugg, C.; Sass, R. L. *Acta Crystallogr.* **1965**, *18*, 591. (d) Kaminskii, V. F.; Shibaeva, R. P.; Neiland, O. Y. *Zh. Strukt. Khim.* **1976**, *17*, 898.

(43) (a) Alcalde, E.; Dinarés, I.; Frigola, J.; Jaime, C.; Fayet, J.-P.; Vertut, M.-C.; Miravitlles, C.; Rius, J. *J. Org. Chem.* **1991**, *56*, 4223. (b) Castellanos, M. L.; Olivella, S.; Roca, N.; De Mendoza, J.; Elguero, J. *Can. J. Chem.* **1984**, *62*, 687.

the calculated $N(1)^+-C(7)$ bond length at 36.6° (146.60 pm) is smaller than those in the ground state (147.25 pm) and transition state (147.30 pm at $\Phi = 89.2°$), respectively. However, upon further rotation to the ground state, the cost in steric repulsion to achieve planarity and, as a consequence, elongation of the $N(1)^+-C(7)$ bond is apparently surmounted by the extra stability that results from the attractive strengths mentioned above, so that, as outlined in Figure 1, a minimum at $\Phi = 1.9°$ is reached.

The sensitive balance between these factors is reflected in available experimental data of model systems such as 2,2′- and 4,4′-bipyridine which are known to be planar in the crystalline state[46] but twisted in the gaseous phase as well as in benzene solution (>20° and 37.2°, respectively[47]). Furthermore, X-ray crystallographic data of pyridinium ylides[42] and pyridinium cations[13a] show coplanar as well as twisted pyridinium rings depending on the substitution pattern.

The negative charge is delocalized in the pyrimidine ring which is confirmed by spectroscopic measurements (Table 1). As a consequence, the calculated bond distance between C(7) and N(8) of the mesomeric betaine **8** is considerably shortened in relation to the salt **2** ($\Delta = -7.92$ pm), whereas the C(7)−C(12) bond length is increased ($\Delta = +2.28$ pm). In agreement with the canonical formulae this is due to an alteration of the s characters of the pyrimidine bonds in both systems.

## Experimental Section

**General Methods.** All the reagents used in these experiments were obtained from Aldrich Chemical Co., except for solvents. The 6-chlorouracils **1**[48] and **5**[49] were prepared following the literature procedures. Acetone, MeCN, EtOAc, 1,2-dichloroethane, and dichloromethane were dried and distilled over $P_4O_{10}$. Sodium iodide was dried *in vacuo* at 200 °C. Chemical shift data for $^1H$ and $^{13}C$ NMR spectra were measured relative to tetramethylsilane (TMS) standard in DMSO-$d_6$ unless otherwise noted. IR spectra were measured as 2.5% pellets in KBr. The FABMS spectra were measured in mNBA. For spectrometers used see ref 15b. All melting points were measured using a Boëtius melting apparatus; the values reported are uncorrected. All compounds were dried by overnight heating at 120−160 °C prior to microanalysis. However, in accordance with known hetarenium compounds[13,18] and uracils[15c] some of them are strongly hygroscopic solids (except for **4a**,**d**, **6**, **7b**, **8**, **10b**, **11**) which rapidly picked up water during weighing. The water of hydration indicated in the formulae give the best fit to the values obtained.

**Preparation of the 4-(Dimethylamino)-1-[1,3-dimethyl-2,4-dioxo-1,2,3,4-tetrahydropyrimidin-6-yl]pyridinium Iodide (2d).** A sample of the chloride **2a**[15a] (2.97 g, 5.0 mmol) and NaI (0.97 g, 6.5 mmol) in 50 mL of anhydrous acetone were heated under reflux for 4 h during which time a colorless precipitate formed. This was collected by filtration after cooling, washed with ethanol, and dried *in vacuo* to give the iodide **2d** as colorless solid: mp 288 °C; $^1H$ NMR $\delta$ 3.04 (s, 3H), 3.25 (s, 3H), 3.31 (s, 6H), 6.27 (s, 1H), 7.27 (d, $J = 7.8$ Hz, 2H), 8.38 (d, $J = 7.8$ Hz, 2H); $^{13}C$ NMR failed due to insufficient solubility; IR 1708.8, 1672.2, 1648.2 $cm^{-1}$; EIMS *m/z* 260.3 ($M^+ - H$; 20), 142.0 (100), 122.2 (DMAP; 24). Anal. Calcd for $C_{13}H_{17}IN_4O_2 \cdot 0.75H_2O$: C, 38.86; H, 4.64; N, 13.94. Found: C, 38.82; H, 4.33; N, 13.90.

**Preparation of the 4-(Dimethylamino)-1-[1,3-dimethyl-2,4-dioxo-1,2,3,4-tetrahydropyrimidin-6-yl]pyridinium Trifluoromethanesulfonate (2e).** Under an inert atmosphere, a sample of 2.97 g (5.0 mmol) of the chloride **2a**,[15a] dissolved in 45 mL of 1,2-dichloromethane, was treated dropwise within 0.5 h with 1.11 g (5.0 mmol) of TMSOTf in 10 mL of the same solvent. The solution was heated under reflux for 1 h, concentrated *in vacuo*, and cooled to 8 °C. A colorless precipitate formed which was collected by filtration. Recrystallization from ethyl acetate gave 2.31 g (65%) **2e** as colorless crystals: mp 311−320 °C; $^1H$ NMR $\delta$ 3.04 (s, 3H), 3.25 (s, 3H), 3.31 (s, 6H), 6.28 (s, 1H), 7.26 (d, $J = 8.1$ Hz, 2H), 8.35 (d, $J = 8.1$ Hz; 2H); $^{13}C$ NMR $\delta$ 27.9, 31.7, 38.6, 99.7, 107.8, 120.6 (q, $J_{CF} = 322.2$ Hz), 140.5, 148.9, 150.8, 156.6, 161.1; IR 1712.3, 1676.2, 1655.4 $cm^{-1}$; FABMS *m/z* 261.1 (100, $M^+$). Anal. Calcd for $C_{14}H_{25}F_3N_4O_9S$: C, 34.85; H, 5.22; N, 11.61. Found: C, 34.45; H, 4.73; N, 11.36.

**General Procedure for the Synthesis of the Uracil Complexes 3.** Lewis acids (10.0 mmol) were added under argon to a vigorously stirred solution of 1.74 g (10.0 mmol) of 6-chloropyrimidine-2,4(1*H*,3*H*)-dione **1** in either 30 mL of anhydrous 1,2-dichloroethane (**3a**) or 30 mL of anhydrous ethyl acetate (**3b**−**d**). After a short refluxing period, the solution was concentrated *in vacuo* and cooled to 8 °C. The crystals were collected by filtration, washed with cold solvent, and dried *in vacuo*.

**6-Chloro-1,3-dimethyl-2,4(1*H*,3*H*)-pyrimidinedione/antimony pentachloride complex (3a):** 2.99 g of antimony pentachloride was used to give **3a** (4.02 g, 85%) as a lemon-yellow solid; mp 199−201 °C; $^1H$ NMR $\delta$ 3.15 (s, 3H), 3.44 (s, 3H), 6.06 (s, 1H); $^{13}C$ NMR $\delta$ 160.7, 151.1, 146.3, 101.0, 33.8, 28.2; IR 1704.1, 1654.0, 1585.1 $cm^{-1}$; FABMS *m/z* 263 (3; $SbCl_4$), 228 (23; $SbCl_3$), 193 (48; $SbCl_2$), 174 (53; $M^+$ of **1**), 157 (5; SbCl), 139 (1; $M^+ - Cl$), 121 (4; Sb), 117 (18; $M^+ - MeNCO$). Anal. Calcd for $C_6H_7Cl_6N_2O_2Sb$: C, 15.21; H, 1.49; N, 5.91. Found: C, 15.39; H, 1.53; N, 6.06.

**6-Chloro-1,3-dimethyl-2,4(1*H*,3*H*)-pyrimidinedione/aluminum chloride complex (3b):** 1.33 g of aluminum(III) chloride was added to form **3b** (1.38 g, 45%) as a colorless solid; mp 186−220 °C; $^1H$ NMR $\delta$ 3.15 (s, 3H), 3.43 (s, 3H), 6.07 (s, 1H); $^{13}C$ NMR failed due to insufficient solubility; IR 1704.6, 1656.4, 1589.6 $cm^{-1}$; EIMS *m/z* 174.2 (52, $M^+$ of **1**). Anal. Calcd for $C_6H_7AlCl_4N_2O_2$: C, 23.40; H, 2.29; N, 9.09. Found: C, 23.64; H, 2.26; N, 8.83.

**6-Chloro-1,3-dimethyl-2,4(1*H*,3*H*)-pyrimidinedione/zinc chloride complex (3c):** 1.36 g of zinc chloride was used; evaporation to dryness *in vacuo* gave **3c** (1.76 g, 57%) as yellow, strongly hygroscopic solid; mp 175−190 °C; $^1H$ NMR $\delta$ 3.12 (s, 3H), 3.41 (s, 3H), 6.02 (s, 1H); $^{13}C$ NMR $\delta$ 28.2, 33.8, 100.9, 146.3, 151.1, 160.7; IR 1713.2, 1651.4, 1471.1 $cm^{-1}$; EIMS *m/z* 174.2 (43, $M^+$ of **1**). Anal. Calcd for $C_6H_7Cl_3N_2O_2Zn$: C, 23.22; H, 2.27; N, 9.01. Found: C, 23.08; H, 3.08; N, 9.74.

**6-Chloro-1,3-dimethyl-2,4(1*H*,3*H*)-pyrimidinedione/Boron Trifluoride Complex (3d).** Addition of 1.42 g of boron trifluoride etherate and concentration *in vacuo* gave **3d** (1.93 g, 80%) upon cooling as a colorless, hygroscopic solid: mp 194 °C dec; $^1H$ NMR $\delta$ 3.15 (s, 3H), 3.44 (s, 3H), 6.05 (s, 1H); $^{13}C$ NMR measurements not possible due to insufficient solubility; IR 1704.3, 1654.7, 1606.8 $cm^{-1}$; EIMS *m/z* 174.2 (52, $M^+$ of **1**). Anal. Calcd for $C_6H_7BClF_3N_2O_2$: C, 29.80; H, 2.92; N, 11.58; Found: C, 29.59; H, 4.05; N, 11.37.

**Synthesis of the 3-Methyl-1-[1,3-dimethyl-2,4-dioxo-1,2,3,4-tetrahydropyrimidin-6-yl]imidazolium Iodide (4).** A sample of 1.00 g (5.7 mmol) of **1** in 50 mL of anhydrous acetone was treated with 1.00 g (6.6 mmol) of 1-methylimidazole and 0.90 g (5.7 mmol) of NaI and heated under reflux for 2 h. Upon cooling, a nearly colorless precipitate formed which was collected by filtration, washed with acetone, and

(44) Bock, H.; Ruppert, K.; Näther, C.; Havlas, Z.; Herrmann, H.-F.; Arad, C.; Göbel, I.; John, A.; Meuret, J.; Nick, S.; Rauschenbach, A.; Seitz, W.; Vaupel, T.; Solouki, B. *Angew. Chem.* **1992**, *104*, 564; *Angew. Chem., Int. Ed. Engl.* **1992**, *31*, 550 and literature cited therein.

(45) Given is the total moment ($\Sigma$), the vectorial sum of the dipole moments on the *x*, *y*, and *z* axes: [*x*, C(9)−N(8), *y*, N(8)−C(7), *z*, rectangular to the *xy* plane], 16.365, 0.285, 0.639 (**2**), and 13.133, 0.186, −1.661 (**8**), respectively.

(46) van Niekerk, J. N.; Saunder, D. H. *Acta Crystallogr.* **1948**, *1*, 44.

(47) Cumper, C. W. W.; Grinman, R. F. A.; Vogel, A. I. *J. Chem. Soc.* **1962**, 1188.

(48) Pfleiderer, W.; Schündehütte, K.-H. *Liebigs Ann. Chem.* **1958**, *612*, 158.

(49) Nübel, G.; Pfleiderer, W. *Chem. Ber.* **1962**, *95*, 1605.

dried *in vacuo*: yield 1.97 g (67%); dec > 268 °C; $^1$H NMR $\delta$ 3.14 (s, 3H), 3.24 (s, 3H), 3.96 (s, 3H), 6.27 (s, 1H), 8.02 (m, 1H), 8.11 (m, 1H), 9.64 (s, 1H); $^{13}$C NMR $\delta$ 28.0, 32.0, 36.3, 99.9, 122.4, 124.5, 138.6, 143.5, 150.7, 160.8; IR 1718.0, 1666.2, 1642.1 cm$^{-1}$; FABMS *m/z* 221.9 (44, $M^+ + 3H$), 51.3 (100). Anal. Calcd for $C_{10}H_{10}IN_4O_2 \cdot 4H_2O$: C, 28.79; H, 4.34; N, 13.43. Found: C, 28.63; H, 3.26; N, 13.23.

**Preparation of the 4-(Dimethylamino)pyridinium 6-Chloro-3-methyl-2,4(1*H*,3*H*)-pyrimidinedionate (6).** A sample of 0.16 g (1.0 mmol) of **5** in 100 mL of ethyl acetate was treated with 0.17 g (1.4 mmol) of DMAP. Slow crystallization at rt gave 0.20 g (71%) of **6** as long, yellow needles: dec > 135−137 °C; $^1$H NMR $\delta$ 3.05 (s, 3H), 3.10 (s, 6H), 5.41 (s, 1H), 6.85 (d, $J$ = 7.2 Hz, 2H), 8.19 (d, $J$ = 7.2 Hz, 2H); $^{13}$C NMR $\delta$ 26.7, 40.3, 94.6, 106.8, 141.7, 154.1, 155.8, 156.1, 163.9; IR 1719.6, 1644.8, 1578.8 cm$^{-1}$; EIMS *m/z* 160 (70, $M^+$ of **5**), 122 (83, $M^+$ of DMAP). Anal. Calcd for $C_{12}H_{15}ClN_4O_2$: C, 50.97; H, 5.35; N, 19.81. Found: C, 50.37; H, 5.55; N, 19.39.

**4-(Dimethylamino)-1-[3-methyl-2,4-dioxo-1,2,3,4-tetrahydropyrimidin-6-yl]pyridinium Chloride (7a).** A vigorously stirred suspension of 1.00 g (6.3 mmol) of **5** and 0.95 g (7.8 mmol) of DMAP in 45 mL of 1,2-dichlorobenzene was heated under reflux for 5 h. After cooling, the precipitate was collected by filtration, washed twice with diethyl ether, dried *in vacuo*, and recrystallized from ethyl acetate/ethanol. Slow crystallization gave nearly colorless crystals (1.59 g, 90%): mp >300 °C; $^1$H NMR $\delta$ 3.18 (s, 3H), 3.30 (s, 6H), 6.12 (s, 1H), 7.18 (d, $J$ = 6.9 Hz, 2H), 8.43 (d, $J$ = 6.9 Hz, 2H); $^{13}$C NMR $\delta$ 26.8, 40.3, 93.7, 107.3, 139.5, 148.5, 151.1, 156.8, 162.7; IR 3493.5, 3444.9, 1718.5, 1672.9 cm$^{-1}$; FABMS *m/z* 247.1 (100, $M^+$). Anal. Calcd for $C_{12}H_{15}ClN_4O_2 \cdot 0.75H_2O$: C, 48.65; H, 5.61; N, 18.11. Found: C, 48.67; H, 6.04; N, 18.06.

**Synthesis of 4-(Dimethylamino)-1-[3-methyl-2,4-dioxo-1,2,3,4-tetrahydropyrimidin-6-yl]pyridinium Trifluoromethanesulfonate (7b).** A vigorously stirred solution of **7a** (1.00 g, 3.4 mmol) in 45 mL of anhydrous dichloromethane was treated dropwise under an inert atmosphere with 0.75 g (0.61 mL, 3.4 mmol) of trimethylsilyl trifluoromethanesulfonate in 10 mL of the same solvent. After stirring overnight, the oily residue was filtered off and dried *in vacuo*. Crystallization was finally achieved by addition of 1 mL of diethyl ether and cooling. The product was obtained (0.41 g, 30%) as brownish solid: mp 253−261 °C; $^1$H NMR $\delta$ 3.17 (s, 3H), 3.30 (s, 6H), 6.17 (s, 1H), 7.18 (dd, $J$ = 6.33/1.80 Hz, 2H), 8.38 (dd, $J$ = 6.33/1.83 Hz; 2H); $^{13}$C NMR $\delta$ 26.8, 40.4, 94.6, 107.3, 120.6 (q, $^{19}$F of OTf$^-$), 139.6, 147.8, 150.6, 156.8, 162.4; IR 1716.3, 1673.4, 1277.1 cm$^{-1}$; FABMS *m/z* 248.0 (100, $M^+ + 1$). Anal. Calcd for $C_{13}H_{15}F_3N_4O_5S$: C, 39.39; H, 3.81; N, 14.14. Found: C, 39.21; H, 4.12; N, 14.85.

**Preparation of the 4-(Dimethylamino)-1-(3-methyl-2,4-dioxo-1,2,3,4-tetrahydropyrimidin-6-yl)pyridinium Iodide (7c).** A sample of 0.24 g (1.0 mmol) of the mesomeric betaine **8** in 40 mL of acetone was treated with 0.26 g (1.0 mmol) of a 50% aqueous solution of HI. After 2 h of stirring, the nearly colorless precipitate was collected by filtration and washed with 10 mL of acetone: yield 0.34 g (92%); partial conversion into **8** occurred rapidly; dec > 245 °C; $^1$H NMR $\delta$ 3.15 (s, 3H), 3.29 (s, 6H), 5.96 (s, 1H), 7.13 (d, $J$ = 6.6 Hz, 2H), 8.58 (d, $J$ = 6.6 Hz, 2H); $^{13}$C NMR $\delta$ 26.7, 40.2, 89.7, 107.2, 138.7, 151.5, 153.5, 156.8, 163.8; IR 1736.6, 1643.7, 1584.9 cm$^{-1}$; FABMS *m/z* 248.1 (100, $M^+ + 1$), 247 (21, $M^+$). As the substance extruded HI during weighing, the analysis referred to a 3:1 mixture of **7c** and **8**. Anal. Calcd for $C_{12}H_{14}N_4O_2 \cdot 0.75HI$: C, 42.11; H, 4.34; N, 16.37. Found: C, 42.33; H, 5.08; N, 16.30.

**Preparation of the 6-(4-(Dimethylamino)pyridinio)-3-methyl-2,4(1*H*,3*H*)-pyrimidinedionate (8). Method C (Scheme 4).** A suspension of **5** (0.66 g, 4.1 mmol) and DMAP (1.25 g, 10.3 mmol) in 45 mL of ethyl acetate was refluxed for 4 h. After cooling, the precipitate was filtered off, treated with 30 mL of boiling ethyl acetate, and dried *in vacuo*. The mesomeric betaine was obtained as cream-colored solid (0.79 g, 79%). **Method D (Scheme 4).** A mixture of 0.50 g (4.1 mmol) of DMAP, 0.66 g (4.1 mmol) of **5**, and 1.41 g (4.1 mmol) of sodium tetraphenylborate dissolved in 60 mL of absolute MeCN was heated under reflux for 5 h. Upon concentration *in vacuo* and subsequent cooling, a precipitate was collected by filtration. Recrystallization from 70 mL of ethyl acetate/ethanol (20:1) afforded 0.70 g (70%) of **8**: mp >300 °C; $^1$H NMR $\delta$ 3.10 (s, 3H), 3.27 (s, 6H), 5.70 (s, 1H), 7.06 (d, $J$ = 8.1 Hz, 2H), 8.81 (d, $J$ = 8.1 Hz, 2H); $^{13}$C NMR $\delta$ 26.8, 39.8, 82.6, 107.2, 137.4, 157.0, 157.1, 157.9, 166.0; IR 1652.5, 1577.3, 1482.0 cm$^{-1}$; FABMS: *m/z* 247.1 (100, $M^+ + 1$). Anal. Calcd for $C_{12}H_{14}N_4O_2$: C, 58.52; H, 5.73; N, 22.75. Found: C, 58.04; H, 5.99; N, 22.29.

**Preparation of the 1,2-Bis[6-(4-(Dimethylamino)pyridinio)-3-methyl-2,4-dioxo-1,2,3,4-tetrahydropyrimidin-6-yl]ethylene Bis(hexachloroantimonate) (9).** **8** (0.12 g, 0.48 mmol) was suspended under an inert atmosphere in 15 mL of anhydrous 1,2-dichloroethane and then treated dropwise with 0.28 g (0.12 mL, 0.96 mmol) of antimony pentachloride in 10 mL of the same solvent. After a short period of time, a lemon-yellow precipitate was filtered and dried *in vacuo*: yield 0.50 g (88%); dec > 165 °C; $^1$H NMR $\delta$ 3.18 (s, 3H), 3.30 (s, 6H), 3.90 (s, 2H), 6.16 (s, 1H), 7.17 (m, 2H), 8.39 (m, 2H); $^{13}$C NMR $\delta$ 26.8, 40.8, 45.0, 94.7, 107.3, 139.7, 147.8, 150.6, 156.8, 162.4; IR 1721.8, 1644.2, 1586.0 cm$^{-1}$; FABMS *m/z* 495 (1, $M^+ - C_2H_4$), 248 (86). Anal. Calcd for $C_{26}H_{32}Cl_{12}N_8O_4Sb_2 \cdot 8H_2O$: C, 23.41; H, 4.23; N, 8.40. Found: C, 23.61; H, 3.63; N, 9.39.

**Preparation of 3-Methyl-1-[3-methyl-2,4-dioxo-1,2,3,4-tetrahydropyrimidin-6-yl]imidazolium Chloride (10a).** A solution of 0.70 g (4.4 mmol) of **5** and 0.72 g (0.68 mL, 8.8 mmol) of 1-methylimidazole in 30 mL of chlorobenzene was heated under reflux for 7 h. After cooling, a fine, nearly colorless precipitate deposited, which was filtered off and thoroughly washed with diethyl ether. Recrystallization from ethyl acetate/ethanol (5:1 v:v) yielded 1.05 g (100%) of a colorless solid: mp > 300 °C; $^1$H NMR 3.16 (s, 3H), 3.94 (s, 3H), 6.13 (s, 1H), 7.93 (m, 1H), 8.21 (m, 1H), 9.87 (s, 1H), NH not detectable; $^{13}$C NMR $\delta$ 26.8, 36.3, 90.5, 120.2, 124.3, 136.8, 144.5, 152.1, 163.0; IR 1658.5, 1552.1, 1514.2 cm$^{-1}$; FABMS *m/z* 207.1 (100; $M^+$). Anal. Calcd for $C_9H_{11}ClN_4O_2 \cdot 0.75H_2O$: C, 42.20; H, 4.91; N, 23.08. Found: C, 42.42; H, 5.75; N, 23.07.

**Preparation of the 3-Methyl-1-(3-methyl-2,4-dioxo-1,2,3,4-tetrahydropyrimidin-6-yl)imidazolium Iodide (10b).** A sample of 0.21 g (1.0 mmol) of the betaine **11** in 20 mL of acetone was treated with 0.26 g (1.0 mmol) of a 50% aqueous solution of HI. After 3 h of stirring, the precipitate was collected by filtration, washed with a small amount of acetone, and dried *in vacuo* to yield 0.25 g (76%) of a pale brownish solid: mp 213−220 °C; $^1$H NMR $\delta$ 3.14 (s, 3H), 3.93 (s, 3H), 6.03 (s, 1H), 7.92 (s, 1H), 8.24 (s, 1H), 9.90 (s, 1H); $^{13}$C NMR failed due to insufficient solubility; IR 1736.6, 1643.7, 1405.0, 1221.7, 811.6 cm$^{-1}$; FABMS *m/z* 207 (10, $M^+$), 176 (100). Anal. Calcd for $C_9H_{11}IN_4O_2$: C, 32.35; H, 3.32; N, 16.77. Found: C, 32.13; H, 3.30; N, 16.29.

**Preparation of the 6-(3-Methylimidazolio)-3-methyl-2,4(1*H*,3*H*)-pyrimidinedionate 11. Method B (Scheme 5).** A sample of 0.61 g (3.8 mmol) of **5** in 100 mL of anhydrous MeCN was subsequently treated with 1.30 g (3.8 mmol) of sodium tetraphenylborate and 0.41 g (5.0 mmol) of 1-methylimidazole. After the suspension had been refluxed for 4 h, a precipitate formed on cooling which was collected by filtration. Recrystallization from ethyl acetate gave 0.45 g (58%) of a light brown solid: mp > 300 °C. **Method C.** A sample of 0.58 g (3.8 mmol) of **5** and 0.93 g (11.4 mmol) of 1-methylimidazole in 60 mL of acetone was heated under reflux for 5 h during which time the starting material dissolved. After concentration and cooling overnight, the resulting precipitate was filtered off, washed subsequently with cold ethyl acetate, and recrystallized from ethanol to furnish 0.38 g (49%) of **11**: $^1$H NMR $\delta$ 3.09 (s, 3H), 3.89 (s, 3H), 5.75 (s, 1H), 7.81 (m, 1H), 8.26 (m, 1H), 9.79 (m, 1H); $^{13}$C NMR $\delta$ 26.7, 36.0, 82.0, 118.3, 124.2, 135.0, 152.7, 158.0, 165.8; IR 1645.1, 1609.8, 1588.0 cm$^{-1}$; FABMS *m/z* 207 (4, $M^+ + H$), 205 (9, $M^+ - H$). Anal. Calcd for $C_9H_{10}N_4O_2$: C, 52.42; H, 4.89; N, 27.17. Found: C, 52.42; H, 5.14; N, 26.83.

**Synthesis of the 2,4,6-Trimethyl-1-(3-methyl-2,4-dioxo-1,2,3,4-tetrahydropyrimidin-6-yl)pyridinium Tetraphenylborate (12).** **5** (1.00 g, 6.2 mmol) and 2.14 g (6.2 mmol) of sodium tetraphenylborate were suspended in a solution of 0.76 g (6.2 mmol) of 2,4,6-trimethylpyridine in 50 mL of anhydrous

ethyl acetate and heated under reflux over a period of 4 h. Filtration of the hot solution and slow crystallization yielded 1.72 g (49%) of a cream-colored solid after drying *in vacuo*: mp > 300 °C; $^1$H NMR $\delta$ 2.22 (s, 3H), 2.36 (s, 6H), 3.08 (s, 3H), 5.83 (s, 1H), 6.81 (t, $J$ = 7.17 Hz; 4H), 6.93 (m, 10H), 7.17 (m, 8H); $^{13}$C NMR $\delta$ 20.2, 23.5, 26.6, 98.5, 120.9, 121.4, 125.2 (q, $J_{BC}$ = 2.2 Hz), 135.4, 144.4, 147.4, 151.0, 156.4, 162.0, 163.3 (q, $J_{BC}$ = 49.8 Hz); IR 1712.6, 1658.5, 1638.6, 1605.7 cm$^{-1}$; FABMS: *m*/*z* 370.7 ($2M^+ - 121$, 1), 318.5 ($BPh_4^-$), 244.0 ($M^+ - 2H$, 21), 243.3 (9), 242.4 (65), 164.2 (100, $BPh_2$), 121.3 (60). Anal. Calcd for $C_{37}H_{36}BN_3O_2 \cdot 4H_2O$: C, 69.70; H, 6.95; N, 6.59. Found: C, 69.75; H, 6.07; N, 6.93.

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