which is insufficient for the present value ($\frac{k_H}{k_D}$ = 11.7). Since isotope effects come from the change of stretching and vibrational energy in transition state and a tunnel effect, one or both of these factors must be large for bridgehead free radicals. So long as the energy barrier in hydrogen transfer is not infinitely high nor infinitely wide[11] there is always certain probability that hydrogen atom will leak through. Hence, tunnel[12] effect is the most probable explanation for unusually large isotope effect.

Unlike tert-butyl, adamantyl radical shows no disproportionation and mostly side chain attack on toluene, this radical would be suitable for rho determination in Hammett correlation. Hammett studies with substituted toluene are under investigation.

Acknowledgement. This work was supported in part by the Korea Science and Engineering Foundation.

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Characterization of 2-Aminodihydropyrimidines

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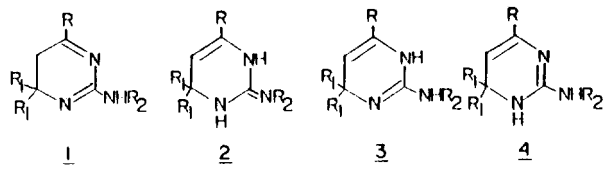
The chemistry of dihydropyrimidines which has been virtually unknown due to the instability of these compounds and the difficulty for purification, has been quite well studied and discussed recently[1]. But the available literature data on 2-aminodihydropyrimidines which are biologically interesting are speculated due to the difficulty to obtain pure compounds. 2-Amino-4,4,6-trimethyl-3,4-dihydropyrimidine has been demonstrated to show a selectivity for the sodium channel in muscle membrane[2] qualitatively similar to that possessed by tetrodotoxin[3] and saxitoxin[4] which contain guanidine ring moieties. Dihydropyrimidines have been known to be important intermediate in the catabolism and anabolism of pyrimidines[5-7]. However the structure of 2-aminodihydropyrimidines is still uncertain due to their instability and impurity. Ealier work[8] demonstrated that 2-aminodihydropyrimidine obtained by the cyclization of guanidine with mesityl oxide is the structure **1**.

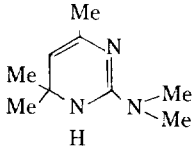
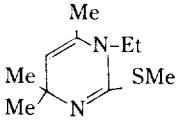


1 **2** **3** **4**

Later work[9] revealed that the reaction of guanidine with mesityl oxide gave a mixture of dihydropyrimidines **2**, **3**, or **4** and its dimer. Recently, Wendelin and Harler[10] reported that a possible structure of 2-alkylaminodihydropyrimidine may be **2** without using suitable model compounds. Previously, we described facile syntheses of pure 2-aminodihydropyrimidines by the reactions of substituted guanidines with α,β-unsaturated ketones[11]. In this paper, we report a plausible structure of **4** by comparing ultra violet spectral data of various good model compounds for 2-aminodihydropyrimidines and unusual instability of 2-aminodihydropyrimidines in protic solvents such as water, methanol, and ethanol. In order to compare uv spectrum of nonconjugative system in **3** with that from **4**, 3,4-dihydro-1-ethyl-2-methylthio-4,4,6-trimethylpyrimidine (**5**, ^{1}H nmr (DMSO-d_6) δ 1.25t, 1.35s, 2.05s, 2.85s, 3.90q, 5.30m; $\lambda_{max}^{MeOH}(\varepsilon)$ 212(6.298 × 10^3)) was prepared by S-methylation of 3,4-dihydro-1-ethyl-2-thio-4,4,6-trimethylpyrimidine[12] with methyl iodide. 3,4-Dihydro-1-ethyl-2-thio-4,4,6-trimethylpyrimidine was prepared by the cyclization of ethylamine and 2-methyl-2-thiocyano-4-pentanone[13].

As a nonconjugative system in **2**, compound **7** is a good model compound because N,N-disubstituted amine by two methyl groups cannot form its imine between C_2 and N in **2**. The hydroiodide(**5**) was easily freed to **6** by treating with aqueous ammonia. The freed dihydropyrimidine(**6**) can neither have a double bond between N_1 and C_2 nor between C_2 and S: namely two nonconjugative double bonds of $C_2=N_3$ and $C_5=C_6$ can exist. The λ_{max} values of various 2-aminodihydro-

Table 1. UV spectra of 2-Aminodihydropyrimidines and Their Related Compounds

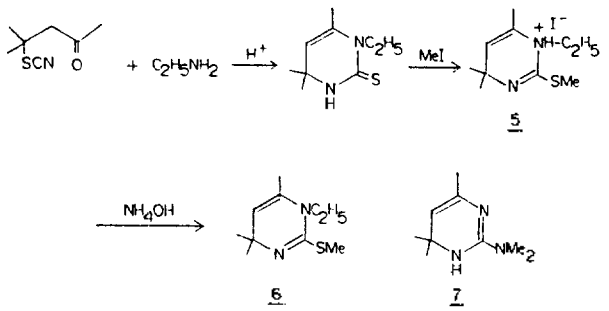
Run	Dihydropyrimidines	solvent	λ_{max} nm(ε)	λ_{max} nm(ε), salt
1	R=R₁=Me, R₂=H (**4a**)	i-PrOH	250(2.29×10³)	240(2.75×10³)
2	R=R₁=Me, R₂=Me (**4b**)	i-PrOH	266(3.12×10³)	236(3.80×10³)
3	R=R₁=Me, R₂=Et (**4c**)	i-PrOH	260(3.66×10³)	240(3.90×10³)
4	 (**6**)	i-PrOH	269(3.41×10³)	—*
5	 (**7**)	MeOH	212(6.30×10³)	219(9.97×10³)

* The salt form is too unstable to measure its λ_{max} and ε value.

Table 2. Percentage of Peak Intensity at λ_{max} after 15 min. in Various Solvents

Run	Dihydropyrimidines[a]	H_2O	MeOH	EtOH	i-PrOH	t-BuOH
1	**4a**	-[b]	57	14	1.5	0
2	**4b**	60	48	25	2.5	0
3	**4c**	53	49	27	3	0

[a]Concentration: ca. 2×10^{-4} mole/l. [b]The decrease of peak intensity was too fast to measure it.

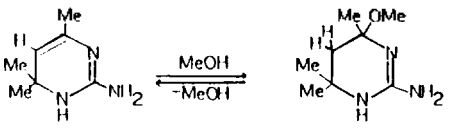


pyrimidines and their hydrochlorides or salts were measured to discuss the position of double bonds in dihydropyrimidines (Table 1). The $C_5=C_6$ bond of **4a-4c** could be readily confirmed by the vinyl proton(δ4.26 in DMSO-d_6) at C_5 position. Since λ_{max} and ε value of **7** which must have only endo double bond are close to those of **4a-4c**, the both two double bonds of **4** and **7** are thought to be in conjugative systems($C_5=C_6-N_1=C_2$). The λ_{max} values of various dihydropyrimidines are much different from those of their salt forms particularly, the N-alkylated dihydropyrimidines synthesized from N-substituted guanidines (**4a-4c**). They show significant blue shifts between free 2-aminodihydropyrimidines and their salt forms.

In the case of the compound **7** and its hydroiodide(Run 5), the both λ_{max} values are quite close each other. Judging from these results, no clean conjugative system of $C_5=C_6-N_1=C_2$ could be observed in the hydrochlorides. The protonation to the guanidine moiety has been well known to be delocalized, because the salt of guanidine possesses very stable conjugative system in $N_1=C_2=N_3$ and N_1-C_2-N. When the guanidine moiety is protonated, the conjugation between two double bonds is much weakened by the more stable resonance of guanidine moiety, and the λ_{max} value of uv spectrum should be blue shifted. The λ_{max} value of nonconjugative system, **7** is about the same to that from its hydroiodide(Run 5). Since the two double bonds of **2** are not in conjugative system, uv spectrum of **2** should be different from **4a-4c** and **6**, and the structure **2** can be ruled out. Thus it can be concluded that 2-aminodihydropyrimidines have conjugative endo double bonds in protic solvent(structure **4**), and they show significant blue shifts in λ_{max} in case of converting to their salt forms. It is noteworthy that **4a-4c** were found to be unstable in protic solvents such as water and methanol, but quite stable in tert-butyl alcohol and isopropyl alcohol. The instability in solvents was followed by measuring the decrease of intensity of uv λ_{max} values in various protic solvents(Table 2).

The order of instability in solvents is water, methanol, ethanol, isopropyl alcohol, and tert-butyl alcohol, which is probably derived due to the steric bulkiness of the solvents. The instability of **4** in protic solvents appears to be due to the nucleophilic attack of the solvent to the carbon at the six position in **4a** to form **A** as shown below.

Though intermediate **A** was not isolated, formation of **A** and existence of an equilibrium between **4a** and **A** were observed by following the peaks of C_6-OMe, C_6-Me, and C_5-H_2 of **A** in the ^1H nmr spectrum.



After heating **4a** solution (ca. 50mg, methanol:600μl), concentrated, and then diluted with DMSO-d_6(500μl) for making nmr sample solution whose ^1H nmr spectrum showed **A**(δC_4-Me_2:1.20, C_5-H_2:1.28, C_6-Me: 1.36, C_6-OMe: 3.01, MeOH: 3.13, cf. **4a** δ C_4-Me_2: 1.20, C_5-H: 4.26, C_6-Me: 1.51). When CD_3OD was added and concentrated, the methoxy peak(δ3.01) remained, but methanol peak(δ3.13) disappeared. When CD_3OD in nmr tube was concentrated at 60°C, the sample solution showed main **4a** together with small amount of **A**, which demonstrated a possibility of equilibrium between **4a** and **A**[14]. In case of tert-butyl alcohol, it may not easily

attack the carbon at six position in **4** due to the bulkiness of the tert-butyl group. Thus compound **4** may be stable in tert-butyl alcohol. More detailed work is being under investigation.

Acknowledgement. This work was partially supported by a generous grant from Korea Science and Engineering Foundation.

References and Notes

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14. When CD_3OD and DMSO-d_6 was completely removed under high vacuum, **4a** was recovered and confirmed.

Photocatalyzed Reduction of Esters by β-Naphthoxyboranes and Lithium tri-β-Naphthoxyborohydride

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On an expectation of changes in reactivities and selectivities of sodium borohydride and as a new attempt to reduce the functional groups that are not reduced under the normal conditions by sodium borohydride, the irradiation effect on borohydride reduction system was investigated[1]. The reduction of esters and ketones with sodium borohydride under uv irradiation showed remarkably different results from ordinary thermal reduction[2]. The quantum yields were larger in non-polar solvents than in polar solvents. The reduction of cyclohexanecarboxylic acid esters with the pure (n, π*) state as the lowest excited state was very much accelerated on photoexcitation. In our previous experiments, all the light was absorbed by carbonyl compounds. We, therefore, investigated the photo-enhanced reduction of esters by various reducing agents having a chromophore themselves and all the light was absorbed by the reducing agents not by carbonyl compounds.

In a typical experiment, an oven dried rubber-capped test tube was flushed with nitrogen and 1.2 mmol of lithium tri-β-naphthoxyborohydride in THF (1.6 m*l*) was introduced into the test tube and diluted with THF to 2.0 m*l*. The reduction was started by the addition of 0.3 mmol of cyclohexanecarboxylic acid ester in THF (1.0 m*l*). The final solution(3 m*l*) was 0.1 M cyclohexanecarboxylic acid ester and 0.4 M hydride. The mixture was irradiated in a merry-go-round for 3.0 h with 334 nm light through a filter solution at room temperature. After irradiation, 2 m*l* of the reaction mixture was transferred into a 5 m*l* volumetric flask and added 1 m*l* of 6N sulfuric acid to destroy the unreacted borohydride. After hydrogen gas evolution ceased, the solution was neutralized with concentrated aqueous sodium hydroxide solution and diluted to 5 m*l* with distilled water and the amount of alcohol produced was determined by gas chromatographic (GC) analysis. A blank solution (2 m*l*) was treated by the same procedure and analyzed by GC for a control. Quantum yields were determined utilizing tris(oxalato) ferrate actinometry and GC using Carbowax 20M 6′×1/8″ column. The results are summarized in Table 1.

The reduction of cyclohexanecarboxylic acid esters with mono-β-naphthoxyborane in THF was carried out irradiating with 334 nm light. All the light was absorbed by the reducing agent itself. The reduction of most of the cyclohexanecarboxylic acid esters with di-β-naphthoxyborane, in particular, was very much accelerated on irradiation as shown in Table 1.

An important photochemical consequence by the change in molecular structure and electronic distribution on excitation is the drastic change of pK_a in S_1 and T_1 states[3]. The pK_a value of β-naphthol is 9, 3, and 8 in the S_o, S_1, and T_1 states, respectively. In general, the pK_a of the triplet state is remarkably close to that of the ground state while the excited singlet state possesses a substantially different pK_a from that of So and T_1 states[3].

The decreased reactivity of lithium tri-β-naphthoxyborohydride and the increased reactivity of β-naphthoxyboranes for the reduction of cyclohexanecarboxylic acid esters on irrandiation can be explained by the increased acidity of β-naphthoxy group in the singlet (π, π*) excited state. Consequently β-naphthoxyborane is more readily coordinated to carbonyl oxygen atom of ester which is electron rich, and