The Lactam-Lactim Tautomerization of Monoamino-Substituted 2-Pyridinols in Tetrahydrofuran

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(Received January 25, 1990)

MINDO/3 calculations have been performed on 3-amino-, 4-amino-, 5-amino-, and 6-amino-2-pyridinols to estimate their molecular geometries. The lactam-lactim tautomerization from amino-2-pyridone to amino-2-pyridinol was expected for 5-amino- and 6-amino-2-pyridinols from the MINDO/3 calculations. In addition, their dimer formation energies were evaluated by the CNDO/2 method. Among the four amino-2-pyridones, 6-amino-2-pyridone has the largest dimer formation energy and 3-amino-2-pyridone the smallest. Furthermore, to certify the tautomerization of 3-amino-, 5-amino-, and 6-amino-2-pyridinols the UV absorption and fluorescence spectra were measured, and compared with those of their *O*-methyl and nuclear *N*-methyl derivatives. From the UV spectral data the equilibrium constants of the lactam-lactim tautomerization were determined for 5-amino and 6-amino derivatives in tetrahydrofuran (THF) at various temperatures. The lactam form is more stable than that of the lactim; the enthalpy changes between two forms of 5-amino and 6-amino derivatives were estimated to be 7.9 and 6.3 kJ mol^{-1}, respectively. The lactam and lactim dimers of these two derivatives were found to be easily formed in THF and ether. From the fluorescence spectral data the lactim dimer of 6-amino derivative was found to be formed in the lowest excited π,π^* singlet state. On the other hand, the 3-amino derivative exists predominantly in the lactam monomer form in both the ground and the lowest excited π,π^* singlet states.

Lactam-lactim tautomerization has been the subject of several investigations.[1,2] In a previous investigation,[3] the absorption spectra of 2-pyridinol and monomethyl-substituted 2-pyridinols were measured, and analyzed with the aid of molecular-orbital calculations. These compounds exist predominantly in the lactam monomer and dimer forms in carbon tetrachloride. The lactam dimer absorption band ($^1A_g \rightarrow {}^1B_u$) was found to appear at wavenumbers higher than those of the monomer ($^1A' \rightarrow {}^1A'$). On the other hand, Peresleni et al.,[4] have described that 6-amino-2-pyridinol exists as a mixture of the lactim and lactam forms. Barlin et al.[5] measured the UV absorption spectra of amino-2-pyridinols, and obtained the ionization constants, from which the structures of mono- and di-cations were analyzed.

In this paper, to ascertain the effect of amino substitution on the lactam-lactim tautomerization and the dimer formation energy of 2-pyridinol the tautomerization and dimer formation energies of monoamino-2-pyridinols were evaluated by the MINDO/3 and CNDO/2 methods.[6-8] Furthermore, the equilibrium constants and enthalpy changes between tautomers of 3-amino-, 5-amino-, and 6-amino-2-pyridinols were determined by UV absorption spectroscopy. The observed UV absorption spectra were also interpreted with the calculated results. In addition, dimer formation in the excited states was analyzed in terms of the fluorescence spectra.

Experimental

Materials. 3-Amino-2-pyridinol was prepared according to a procedure of Salemink.[9] Purification of this compound is accomplished by using the technique of alumina column chromatography with ether as an eluent. 3-Amino-2-methoxypyridine and 3-amino-1-methyl-2(1*H*)-pyridinone were prepared by a procedure of Bickel et al.,[10] and Peresleni et al.,[4] respectively. These compounds were purified by alumina column chromatography using THF as an eluent. The preparation of 5-amino-2-pyridinol, 5-amino-2-methoxypyridine, and 5-amino-1-methyl-2(1*H*)-pyridinone has been described in the literatures.[10,11] Purification of these compounds was performed by repeated silica-gel column chromatography using THF as an eluent. Commercial 6-amino-2-pyridinol (Aldrich) was recrystallized from acetonitrile. 6-Amino-2-methoxypyridine[10] was prepared from commercial 2,6-dichloropyridine (Aldrich) by way of 6-amino-2-chloropyridine.[12] 6-Amino-1-methyl-2(1*H*)-pyridinone was prepared from 6-amino-2-pyridinol by methylation with diazomethane. The compound was purified by repeated silica-gel column chromatography using ether as an eluent.

The ^{1}H and ^{13}C NMR spectra of these compounds were taken on a JEOL FX90Q spectrometer using TMS as an internal standard. The amino-substituted pyridinols have the following ^{1}H and ^{13}C NMR spectroscopic properties:

3-Amino-2-pyridinol: ^{1}H NMR (DMSO-d_6) δ=5.0 (2H, m, NH_2), 6.01 (1H, J=5 Hz, t, ring), 6.45 (1H, J=5Hz, d, ring), 6.63 (1H, J=5Hz, d, ring), 11.4 (1H, m, NH); ^{13}C NMR (DMSO-d_6) δ=107.0 (d), 112.2 (d), 120.9 (d), 139.2 (s), 158.2(s).

3-Amino-2-methoxypyridine: ^{1}H NMR ($CDCl_3$) δ=3.87 (3H, s, CH_3), 4.9 (2H, m, NH_2), 6.8 (2H, m, ring), 7.4 (1H, m, ring); ^{13}C NMR ($CDCl_3$) δ=53.2 (q), 118.0 (d), 119.3 (d), 133.1 (s), 152.5 (s).

3-Amino-1-methyl-2(1*H*)-pyridinone: ^{1}H NMR (DMSO-d_6) δ=3.44 (3H, s, CH_3), 5.1 (2H, m, NH_2), 6.01 (1H, t, J=5Hz, ring), 6.46 (1H, dd, J=1 and 5Hz, ring), 6.98 (1H, dd, J=1 and 5Hz, ring); ^{13}C NMR (DMSO-d_6) δ=36.8 (q), 106.3 (d), 110.3 (d), 132.6 (d), 138.3 (s), 157.5 (s).

5-Amino-2-pyridinol: ^{1}H NMR (DMSO-d_6) δ=3.6 (2H, m, NH_2), 4.3 (1H, m, NH), 6.25 (1H, d, J=5 Hz, ring), 6.77 (1H, s, ring), 7.06 (1H, d, J=5Hz, ring); ^{13}C NMR (DMSO-d_6) δ=105.1 (d), 109.9 (d),118.9 (d), 137.6 (s), 156.5 (s).

5-Amino-2-methoxypyridine: ^{1}H NMR (DMSO-d_6) δ= 3.74 (3H, s, CH_3), 4.75 (2H, m, NH_2), 6.56 (1H, d, J=5 Hz, ring), 7.07 (1H, dd, J=2 and 5 Hz, ring), 7.54 (1H, d, J=2Hz, ring); ^{13}C NMR (DMSO-d_6) δ=52.9 (q), 110.1 (d), 126.7 (d), 131.4 (d), 139.3 (s), 156.0 (s).

5-Amino-1-methyl-2(1*H*)-pyridinone: ^{1}H NMR (DMSO-d_6) δ=3.34 (3H, s, CH_3), 3.99 (2H, m, NH_2 6.27 (1H, d, J=5 Hz,ring),6.87 (1H, d, J=2 Hz,ring), 7.10 (1H, dd, J=2 and 5 Hz, ring); ^{13}C NM (DMSO-d_6) δ=36.0 (q), 119.5 (d), 120.4 (d), 129.4 (s), 134.9 (d), 159.2 (s).

6-Amino-2-methoxypyridine: ^{1}H NMR (DMSO-d_6) δ=3.77 (3H, s, CH_3), 5.86 (2H, m, NH_2), 5.93 (1H, d, J=5 Hz, ring), 5.06 (1H, d, J=5Hz, ring), 7.30 (1H, t, J=5 Hz, ring); ^{13}C NMR (DMSO-d_6) δ=55.3 (q), 95.8, (d), 99.1 (d), 139.6 (d), 158.5 (s), 162.9 (s).

6-Amino-1-methyl-2(1*H*)-pyridinone: ^{1}H NMR (DMSO-d_6) δ=3.32, (3H, s, CH_3), 5.44 (1H, d, J=5 Hz, ring), 5.49 (1H, d, J=5 Hz, ring), 6.49 (2H, m, NH_2), 7.10 (1H, t, J=5 Hz, ring); ^{13}C NMR (DMSO-d_6) δ=28.0 (q), 87.1 (d), 100.9 (d), 140.2 (d), 153.2 (s), 161.8 (s).

The presence of the lactim form in amino-2-pyridinols could not be confirmed from the ^{1}H and ^{13}C NMR spectra.

Purification of tetrahydrofuran (THF), acetonitrile, and ether was performed by conventional methods.[13]

Apparatus. The UV absorption spectra were measured with a Hitachi model 323 spectrophotometer. The measurement of the absorption spectra at various temperatures (20 °C—−90 °C) was carried out on samples in 10 mm square quartz cells placed in a metallic Dewar vessel with two quartz windows. The temperature regulation of the samples was achieved by using liquid nitrogen. The fluorescence spectra were recorded with instrumentation already described;[14] the fluorescence quantum yields were normalized to a value of 0.55 for quinine sulfate in 0.1 equiv-H_2SO_4 at room temperature.[15]

Calculation Method and Molecular Model

Since the observed molecular structures of monoamino-2-pyridinols were unavailable, their molecular geometries were obtained by the MINDO/3 method[6] with full geometry optimization using the original standard parameters under the assumption that the molecules are planar. For the dimers of the lactam form, a C_{2h} symmetric model which has parameters of R and θ (Fig. 1) was used. The composite parts of the dimer are invariant upon dimer formation. The dimer formation energies (ΔH_D) of monoamino-substituted 2(1*H*)-pyridinones were obtained by the CNDO/2 method according to the same procedure used for the previous dimer model.[16]

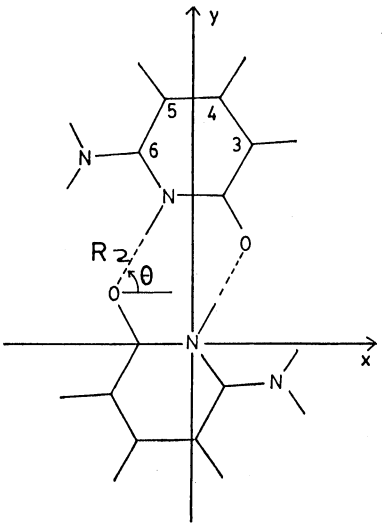


Fig. 1. The dimer model of monoamino-2(1*H*)-pyridinones belongs to the points group of C_{2h}. The R and θ stand for the parameters to be optimized by the CNDO/2 method.

The transition energies, oscillator strengths, and band maxima of the monomer and dimer of the lactam form and the monomer of the lactim form were calculated by the CNDO/CI method.[3,16]

Results and Discussion

Theoretical. Table 1 shows the total energies, E_T, and dipole moments, μ, of the models of monoamino-2-pyridinol, as calculated by the MINDO/3 method. The present calculation shows that (1) the lactam form is more stable than the lactim form in monoamino-2-pyridinol and (2) the lactam-lactim tautomerization energy of 6-amino-substituent is the smallest of the compounds listed in Table 1. Kuzuya et al.[2] has also elucidated same results for 2-pyridinol and several monosubstituted 2-pyridinols using the MINDO/3 method with full geometry optimization. Recently, a calculation of the lactam-lactim tautomerization energy of 2-pyridinol was carried out by the ab initio MO method at various levels of approximation.[17,18] The calculated results showed that the lactam form is more stable than the lactim form at approximations of 3-21G, 6-31G, 6-31G*, and 6-31G with MP2,[17] while the lactim form is more stable than the lactam form at the 6-31G** approximation.[18] However, the energy difference between the lactam and lactim forms is relatively small in both results and it depends on the level of approximation. Therefore, the present calculated results of tautomerization should be ascertained by the ab initio MO method. The calculated energy difference between the lactam and lactim forms of 6-amino-2-pyridinol is 4.73

Table 1. The Total Energies (E_T), Energy Differences (ΔE_T), and Dipole Moments (μ) of the Optimized Models of Monoamino-Substituted 2-Pyridone and 2-Pyridinol, as Calculated by the MINDO/3 Method

Compound	$-E_T$/eV	ΔE_T/kJ mol^{-1}	μ/D
3-Amino-2-pyridone	1419.296	0	2.682
3-Amino-2-pyridinol	1419.092	19.7	0.942
4-Amino-2-pyridone	1419.588	0	5.473
4-Amino-2-pyridinol	1419.371	20.9	2.022
5-Amino-2-pyridone	1419.194	0	5.281
5-Amino-2-pyridinol	1419.100	9.08	1.958
6-Amino-2-pyridone	1419.790	0	5.609
6-Amino-2-pyridinol	1419.741	4.73	2.284

Table 2. The Hydrogen Bond Energies (ΔH_D), Corrected Hydrogen Bond Energies (ΔH_{Dc}), Equilibrium Distances (R_e) and Angles (θ) of Monoamino-Substituted 2-Pyridone Dimers, as Calculated by the CNDO/2 Method

Dimer	Sym.	R_e/Å	θ/deg	$-\Delta H_D$/kJ mol^{-1}	$-\Delta H_{Dc}$/kJ mol^{-1}
3-Amino-2-pyridone	C_{2h}	1.48	65.8	84.9	38.6
4-Amino-2-pyridone	C_{2h}	1.45	63.8	101	45.7
5-Amino-2-pyridone	C_{2h}	1.47	70.8	91.3	41.4
6-Amino-2-pyridone	C_{2h}	1.46	62.0	109	49.1
2-Pyridone	C_{2h}	1.46	65.7	95.7	43.4

kJ mol^{-1}, while the corresponding values[2)] of 2-pyridinol and 6-methyl-2-pyridinol are 15.6 and 12.8 kJ mol^{-1}, respectively. The lactim forms of the latter two compounds were not observed in previous experiments.[3,16)] The smaller value of 6-amino-2-pyridinol suggests the possibility of the lactim form. On the other hand, since the energy difference values (19.7 and 20.9 kJ mol^{-1}) of 3- and 4-amino-2-pyridinols are larger than those of 2-pyridinol and 6-methyl-2-pyridinol, the formation of their lactim forms may be difficult in the ground state.

The calculated dimer formation energies (ΔH_D), equilibrium distances (Re), and angles (θ) of the lactam form are shown in Table 2 with the corresponding values for a 2-pyridinone model which was optimized by the MINDO/3 method. The calculated dimer formation energies were corrected by using the previous procedure.[16)] The corrected dimer formation energies (ΔH_{Dc}) are listed in Table 2. The dimer formation energy of 3-amino-2-pyridone is the smallest among the four amino substituents. Qualitatively, the charge density of the oxygen atom of 3-amino-2-pyridone is the smallest among the four compounds. It is noteworthy that the calculated dimer formation energies of 5- and 6-amino-2-pyridones are larger than that of 2-pyridone, while the corresponding value for 3-amino-2-pyridone is smaller than that of 2-pyridone.

The calculated band maxima of the first and second π-π* absorption spectra of the monomer and dimer of lactam form and those of the lactim monomer form are plotted against the position of amino substitution in Fig. 2. The theoretical spectral behaviors of amino substituents are similar to those of methyl substituents.[3)]

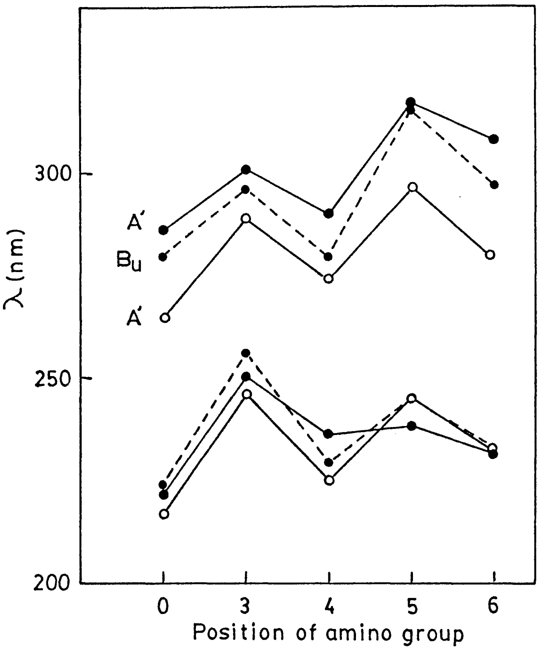


Fig. 2. Plots of the calculated band maxima of the first and second π-π* absorption spectra of the lactam and lactim forms of mono-amino-2-pyridinol vs. the position of amino group. (a) —●—: Monomer of lactam form. (b) --●--: Dimer of lactam form. (c) —○—: Monomer of lactim form. The zero position corresponds to those of 2-pyridinol.

UV Absorption Spectra of Monoamino-2-pyridinols. The concentration of the amino-2-pyridinols was kept constant, and their UV absorption spectra were observed for various concentrations of 0—11 mol dm^{-3} of acetonitrile (Fig. 3), with those of amino-2-methoxypyridines (*O*-methyl derivatives) and amino-1-methyl-2(1*H*)-pyridinones (nuclear *N*-methyl derivatives) in THF. From Fig. 3 it was found that in THF and the THF-acetonitrile mixed solvent 3-amino-2-pyridinol exists in the lactam form, since its spectrum resembles that of the nuclear *N*-methyl derivative; however, it differs from that of *O*-methyl derivative. For 5-amino- and 6-amino-2-pyridinols in THF and its mixed solvent, the existence of lactam-lactim equilibrium is considered since some clear isosbestic points have been observed in the UV spectra (Fig. 3); these spectra are characterized by an overlapping of those of the *O*-methyl and *N*-methyl derivatives, respectively. The absorption band maximum of the lactim form is found to appear at a shorter wavelength than that of the lactam form. The lactam form becomes predominant with an increase in the acetonitrile concentration. The dielectric constants of THF and acetonitrile are 5.61 and 37.5, respectively. Accordingly, the lactam form increases with an increases in the polarity of the solvent. This trend is in line with the magnitude of the calculated dipole moments of the lactam and lactim forms shown in Table 1.

The UV absorption spectra of 5- and 6-amino-2-

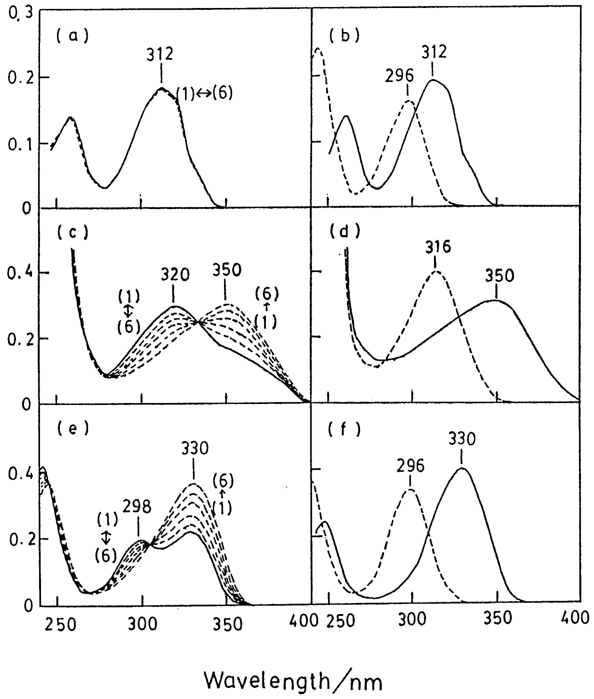


Fig. 3. UV absorption spectra of monoamino-2-pyridinols in THF–acetonitrile mixed solvents with those of their *O*-methyl and nuclear *N*-methyl derivatives at room temperature. (a): 3-Amino-2-pyridinol. (b): 3-Amino-2-methoxypyridine (----) and 3-amino-1-methyl-2(1*H*)-pyridinone (——). (c): 5-Amino-2-pyridinol. (d): 5-Amino-2-methoxypyridine (----) and 5-amino-1-methyl-2(1*H*)-pyridinone (——). (e): 6-Amino-2-pyridinol. (f): 6-Amino-2-methoxypyridine (----) and 6-amino-1-methyl-2(1*H*)-pyridinone (——). Concentrations of amino-2-pyridinols and their *O*-methyl and nuclear *N*-methyl derivatives: 4×10^{-5} mol dm^{-5}, concentrations of acetonitrile (mol dm^{-3}): (1) 0, (2) 0.7, (3) 2.3, (4) 5.7, (5) 9.5, (6) 11.0.

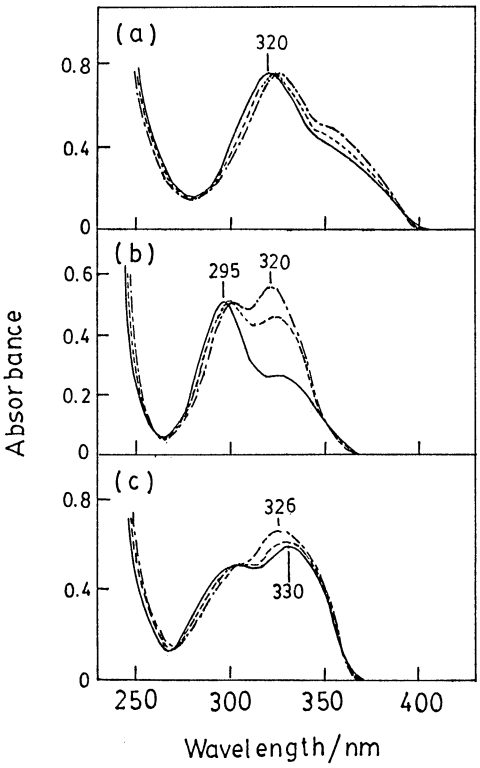


Fig. 4. UV absorption spectra of 5-amino-2-pyridinol in THF (a), and 6-amino-2-pyridinol in ether (b) and in THF (c) at room temperature. Concentrations of these amino-2-pyridinols were 1×10^{-5} mol dm^{-3}, 100 mm cell (——); 1×10^{-4} mol dm^{-3}, 10 mm cell (----); 1×10^{-3} mol dm^{-3}, 1 mm cell (— - —).

pyridinols were observed at concentrations of 10^{-5}—10^{-3} mol dm^{-3} in THF and in ether (Fig. 4); however, the 5-amino derivative is insoluble in ether. The UV spectra of 5-amino- and 6-amino-2-pyridinols change with their concentrations, as is shown in Figs. 4a, 4b, and 4c. In the case of the 6-amino derivative in ether, the band maximum at 295 nm, which corresponds to the monomer of the lactim form, shifts towards a longer wavelength with an increase in the concentration of the 6-amino derivative; the absorption band at 330 nm, which corresponds to the monomer of lactam form, shifts toward a shorter wavelength accompanying an enhancement of the intensity. These shifts would be due to the dimer formation of lactim and lactam, respectively. The spectral behavior is in line with the calculated results shown in Fig. 2. Further, the lactam dimer of 6-amino-2-pyridinol becomes appreciably predominant with an increase in the concentration. For methyl-2-pyridinols no band shift toward longer wavelengths, owing to lactim dimer formation, has been observed; the shorter wavelength shift due to lactam dimer formation merely appeared, as is shown in a previous paper.[3)]

The concentration effect of 6-amino-2-pyridinol on the absorption spectrum in THF is not so conspicuous as that in ether, as shown in Fig. 4b. In THF lactim monomer formation and lactam and lactim dimer formations are poorer than in ether, since the polarity of THF (dielectric constant; 5.61) is larger than that of ether (1.15). The spectral behavior of the 5-amino derivative with a change in its concentration in THF (Fig. 4a) is also similar to that of the 6-amino derivative in THF (Fig. 4c).

On the other hand, there was no change in the UV absorption spectrum of 3-amino-2-pyridinol within this concentration range in either THF or ether; its spectrum was extremely similar to that of the *N*-methyl derivative shown in Fig. 3b. Consequently, the 3-amino derivative is stable in the lactam monomer form in these solvents. The introduction of a methyl group at the 3-position tends to decrease the dimer formation energy of 2-pyridone.[2)] This is in good accord with the present calculated result for the 3-amino-2-pyridone dimer.

The UV absorption spectra of monoamino-2-pyridinols and their *O*-methyl and nuclear *N*-methyl

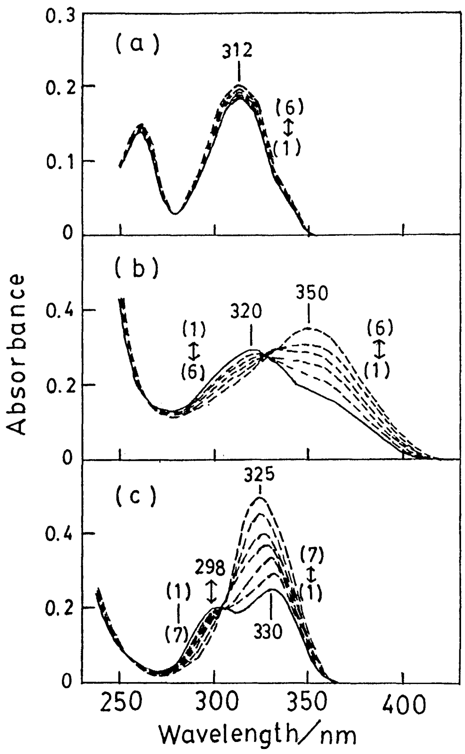
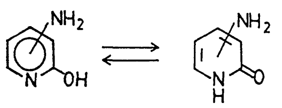


Fig. 5. Temperature effect on UV absorption spectra of 3-amino- (a), 5-amino- (b), and 6-amino-2-pyridinols (c) in THF: (1) 20 °C, (2) 0 °C, (3) −20 °C, (4) −40 °C, (5) −60 °C, (6) −80 °C, (7) −90 °C. Concentrations of these amino-2-pyridinols were 4× 10^{-5} mol dm^{-3}.

derivatives were measured at various temperatures (20—90 °C). Some examples of the experimental results are shown in Fig. 5. In the case of their *O*-methyl and *N*-methyl derivatives and 3-amino-2-pyridinol (Fig. 5a) the band intensities of the absorption spectra increased merely with decreasing temperature. On the other hand, in the 5-amino and 6-amino derivatives, the shapes of the absorption spectra changed and clear isosbestic points appeared with decreasing temperature, as is shown in Figs. 5b and 5c.

From the UV spectral change shown in Fig. 5c, the 6-amino derivative was found to exist in the lactam and lactim monomer forms near 20 °C to −40 °C and in the dimer forms in the range near −50 °C to −90 °C. The lactam-lactim tautomerization between the monomers of amino-2-pyridinols can be represented by the following equilibrium:



The equilibrium constants, K_T, of the tautomerization reactions were obtained by the use of the following equation:

$$K_T = \frac{[Y]}{[X]}, \tag{1}$$

where

$$[X] = \frac{\begin{vmatrix} A_1 & \varepsilon_{Y1} \\ A_2 & \varepsilon_{Y2} \end{vmatrix}}{\begin{vmatrix} \varepsilon_{X1} & \varepsilon_{Y1} \\ \varepsilon_{X2} & \varepsilon_{Y2} \end{vmatrix}}, \quad [Y] = \frac{\begin{vmatrix} \varepsilon_{X1} & A_1 \\ \varepsilon_{X2} & A_2 \end{vmatrix}}{\begin{vmatrix} \varepsilon_{X1} & \varepsilon_{Y1} \\ \varepsilon_{X2} & \varepsilon_{Y2} \end{vmatrix}}. \tag{2}$$

Here, $[X]$ and $[Y]$ are the equilibrium concentrations of the lactim and lactam isomers, respectively; A_1 and A_2 are the observed absorbances at two wavelengths, λ_1 and λ_2. ε_{X1} and ε_{X2} are the molar absorption coefficients of lactim at λ_1 and λ_2, while ε_{Y1} and ε_{Y2} are the corresponding ones of lactam. Here, the absorption coefficients of ε_{Xi} and ε_{Yi} of *O*-methyl and *N*-methyl derivatives were used for those of the lactim and lactam isomers.

The enthalpy changes (ΔH_T) accompanying tautomer formation can be obtained from knowledge of the variation of K_T with the temperature. In the present experiment the values of K_T were determined for each compound at seven temperatures within the range from 20 °C to −40 °C (Fig. 6). The lactam form is more stable than the lactim form and the values of K_T and ΔH_T at 20 °C are 2.2 and −7.9 kJ mol^{-1} for the 5-amino derivative and 0.53 and −6.3 kJ mol^{-1} for 6-amino derivative, as given in Fig. 6. No corresponding values for the 3-amino derivative were obtained, since this compound is very stable (energetically) in the lactam form. These values of the 6-amino derivative are approximately equal to those of the 5-amino deriv-

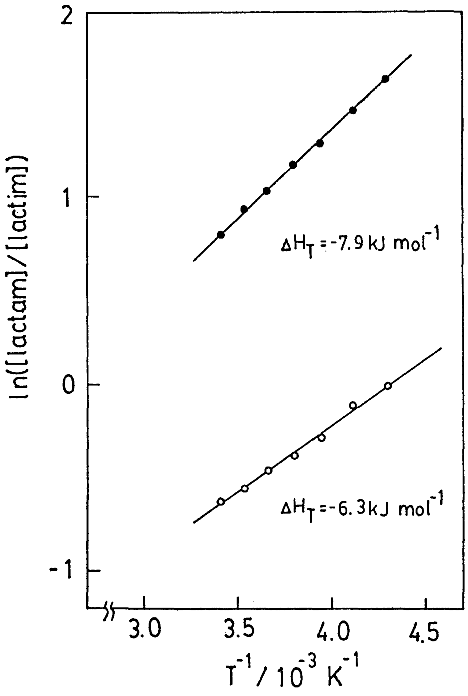


Fig. 6. Plots of ln ([lactam]/[lactim]) vs. T^{-1} for 5-amino- (●) and 6-amino-2-pyridinol (○) in THF. The values in this figure show the enthalpy changes (ΔH_T) accompanying tautomer formation and were determined from the slope of the curve in the logarithmic plots.

ative. Furthermore, these values are approximately close to those of 2-pyridinol in cyclohexane (K_T=1.6 and ΔH_T=−4.7 kJ mol^{-1}).[1]

Fluorescence Spectra of Monoamino-2-pyridinols. The fluorescence spectra of monoamino-2-pyridinols were measured in THF containing various amounts of acetonitrile at room temperature (Fig. 7). Further, the fluorescence band maxima and fluorescence quantum yields (ϕ_f) of monoamino-substituted 1-methyl-2(1*H*)-pyridinones and 2-methoxypyridines in THF and in CH_3CN are given in Table 3. The ϕ_f value of 5-amino-1-methyl-2(1*H*)-pyridinone in CH_3CN is of the largest among the six compounds, while that of 6-amino-1-methyl-2(1*H*)-pyridinone in CH_3CN is of the smallest. The value of ϕ_f of 2-methoxypyridine is 0.003 in CH_3CN[19] and 0.014 in an alcohol (ethanol containing 10% methanol) mixture,[20] and that of 1-methyl-2(1*H*)-pyridinone is 0.006 in an alcohol mixture.[20] The introduction of an amino group to 2-methoxypyridine and 1-methyl-2(1*H*)-pyridinone tends to increase the fluorescence quantum yield; by introduction of an amino group at the 5-position the ϕ_f value is greatly increased.

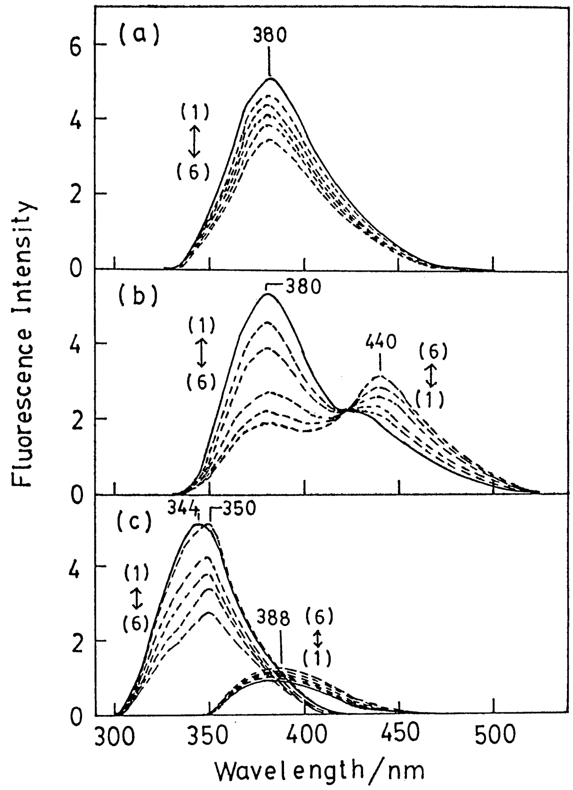


Fig. 7. Fluorescence spectra of lactam form of 3-amino-2-pyridinol obtained by excitation at 290 nm (a), those of lactim and lactam forms of 5-amino-2-pyridinol obtained by excitation at 310 nm (b), and those of lactim and lactam forms of 6-amino-2-pyridinol obtained by excitation at 290 nm (c) (left) and at 330 nm (c) (right), respectively. These spectra were measured in THF-acetonitrile mixed solvent at room temperature. Concentrations of amino-2-pyridinols and acetonitrile are equal to those ones in Fig. 3.

As shown in Fig. 7a, the fluorescence spectrum of 3-amino-2-pyridinol in THF shows only one peak; the fluorescence is quenched in the presence of acetonitrile. However, the band maximum at 380 nm does not shift and it is in fair agreement with that (380 nm) of 3-amino-1-methyl-2(1*H*)-pyridinone (Table 3). The ϕ_f values of 3-amino-2-pyridinol in THF and CH_3CN were 0.23 and 0.12, respectively. These values in THF and CH_3CN are close to the values of 0.27 and 0.17 of 3-amino-1-methyl-2(1*H*)-pyridinone, but differ from the values of 0.13 and 0.19 of 3-amino-2-methoxypyridine. From these results it is thought that 3-amino-2-pyridinol in THF and the THF-acetonitrile mixed solvent exists mainly in the lactam monomer form in the excited state as well as in the ground state. On the other hand, 5-amino-2-pyridinol in these solvents shows two fluorescence bands by excitation with the wavelength which the absorption spectra of its lactam and lactim overlap (Fig. 7b). The fluorescence bands at 380 and 440 nm can be assigned to emission from the lactim and lactam forms, respectively, on the basis of the fluorescence characteristics of *O*-methyl and *N*-methyl deriv-

Table 3. The Fluorescence Band Maxima ($\lambda_{f\ max}$) and Fluorescence Quantum Yields (ϕ_f) of Monoamino-Substituted 1-Methyl-2(1*H*)-pyridinones and 2-Methoxypyridines in THF and CH_3CN

Compound	Solvent	$\lambda_{f\ max}$/nm	ϕ_f
3-Amino-1-methyl-2(1*H*)-pyridinone	THF	383	0.27
	CH_3CN	380	0.17
3-Amino-2-methoxypyridine	THF	348	0.13
	CH_3CN	343	0.19
5-Amino-1-methyl-2(1*H*)-pyridinone	THF	440	0.64
	CH_3CN	438	0.91
5-Amino-2-methoxypyridine	THF	371	0.36
	CH_3CN	373	0.30
6-Amino-1-methyl-2(1*H*)-pyridinone	THF	380	0.011
	CH_3CN	380	0.010
6-Amino-2-methoxypyridine	THF	339	0.22
	CH_3CN	337	0.09

atives given in Table 3. A clear isoemissive point is observed at 422 nm in the fluorescence spectra. These results indicate that an equilibrium of lactam-lactim tautomerization exists in the excited state as well as in the ground state.

In the case of 6-amino-2-pyridinol in THF and the THF-acetonitrile mixed solvent, the fluorescence band maximum was observed near 350 nm upon excitation at 290 nm, at which the absorption bands of lactim and lactam overlap; the corresponding one at 388 nm could only be observed by excitation in the lactam absorption region (Fig. 7c). Whereas the fluorescence of the lactam of 5-amino derivative would be intense from an analogy of the ϕ_f value of 5-amino-1-methyl-2(1*H*)-pyridinone, and it appears clearly (Fig. 7b). Therefore, the fluorescence spectral result of the 6-amino derivative in Fig. 7c seems not to resemble that of the 5-amino derivative shown in Fig. 7b. However, the fluorescence which appeared at 388 nm for the 6-amino derivative is considered to be weak from the ϕ_f value of 6-amino-1-methyl-2(1*H*)-pyridinone, and to be hidden by an intense fluorescence band observed near 350 nm. Further, the fluorescence band near 350 nm for the 6-amino derivative has a weak shoulder band near 330 nm. This band may be due to the lactim monomer, since the fluorescence band maximum of 6-amino-2-methoxypyridine is observed at 337 nm in acetonitrile. The fluorescence at 350 nm (described above) should be assigned to the lactim dimer of 6-amino-2-pyridinol. Note that the lactim dimer is more readily formed in the excited state than in the ground state, since the ring N atom of pyridine in the excited state is expected to become more basic than in the ground state. On the other hand, it is hard to assign the fluorescence band near 388 nm to either the lactam monomer and/or the dimer of 6-amino-2-pyridinol for the weak and broad band.

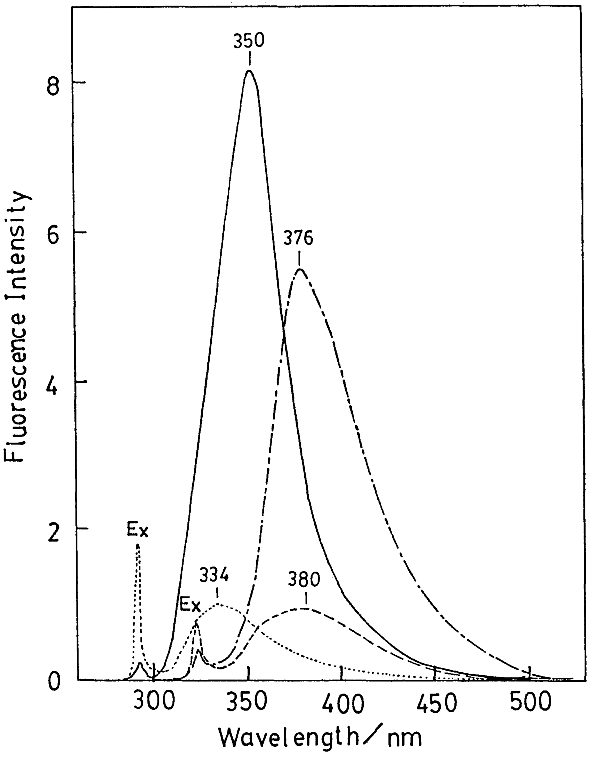


Fig. 8. Fluorescence spectra of lactim monomer (······), lactim dimer (——), lactam monomer (----), and lactam dimer (— - —) of 6-amino-2-pyridinol in ether at room temperature. (······); Concentration: 1×10^{-5} mol dm^{-3}, excitation wavelength: 290 nm. (——); Concentration: 1×10^{-3} mol dm^{-3}, excitation wavelength: 290 nm. (----); Concentration: 1×10^{-4} mol dm^{-3}, excitation wavelength: 325 nm. (— • —); Concentration: 1×10^{-3} mol dm^{-3}, excitation wavelength: 325 nm.

In ether, the fluorescence spectra of the lactim and lactam of the monomer and dimer are easily observed as follows. The fluorescence spectra of 6-amino-2-pyridinol in ether are presented in Fig. 8 for the concentration range 10^{-5}—10^{-3} mol dm^{-3}. The flurescence spectra at 334, 350, 376, and 380 nm can be assigned to emission from the lactim monomer and dimer and the lactam dimer and monomer, respectively.

This work was supported by grants from the Research and Development Center of Engineering of Tokyo Denki University. The authors thank Dr. Michio Fukunaga of the University of Tokyo for his kind advice during this study. One of the authors (K.I.) also acknowledges his gratitude for the financial assistance of Sumitomo Seika Chemicals Co., Ltd. and for the staffs of the T.D.U. Computer Center.

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