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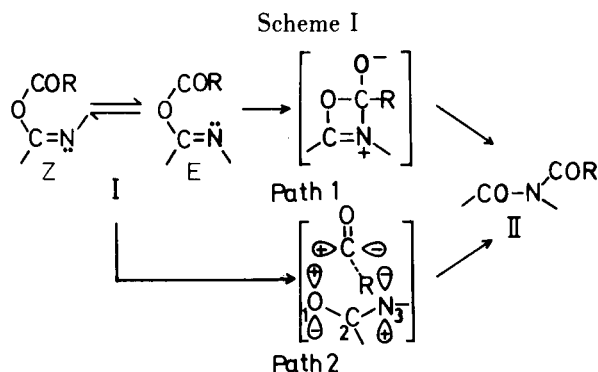
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The title isoimides rearrange upon heating to the corresponding imides through a [1,3] O-N aroyl transfer. The reaction is slightly accelerated by electron withdrawing substituents in the migrating moiety and retarded by electron donating as it is suggested by the positive (+0.5) Hammett ρ value. The mechanism operating is either a rate determining nucleophilic attack by the nitrogen lone pair on the carbonyl carbon or a sigmatropic [$\pi 2s + \sigma 2a$] process which does not involve the lone pair of electrons on nitrogen and the π orbitals of the carbonyl group.

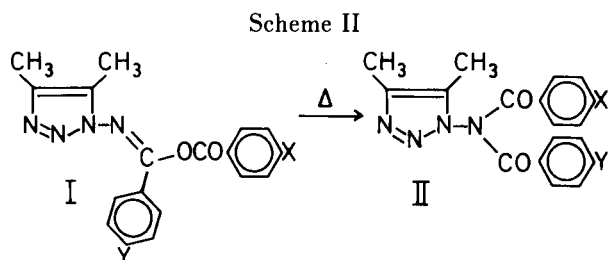
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The isomerization of isoimides I to imides II has attracted a great deal of attention in the past [1-14]. Of the various mechanisms proposed two extreme received considerable merit (Scheme I). The first (Path 1) involves the formation of a polar four-membered intermediate while the second (Path 2) is a concerted [1,3] sigmatropic shift.



In order for the *O*-acyl compound (isoimide, I) to give *via* Path 1 the *N*-acyl form (imide, II), an *Z* \rightarrow *E* isomerization is required. Whether the *Z* \rightarrow *E* isomerization or the formation of the four-membered zwitterionic intermediate is the rate determining step for the overall process seems to depend on the nature of the particular isoimide and both pathways have been proposed by Hegarty [7] and Curtin [5] respectively.

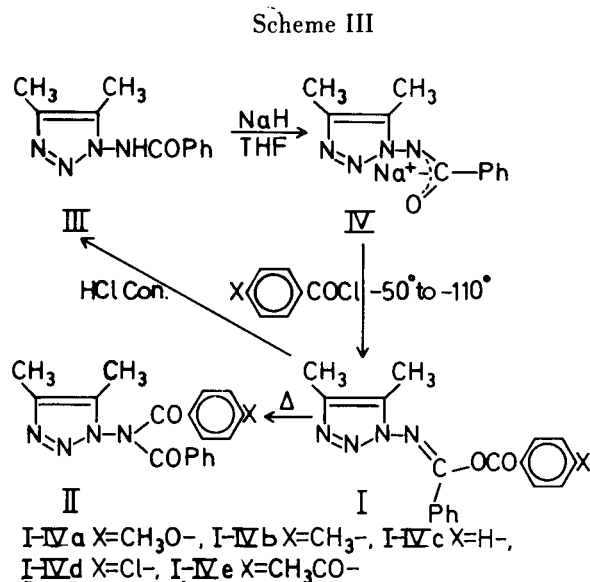
During the past a few years Alexandrou and Coworkers [13,14] had been studying the thermal rearrangement of the 1-(α -aroyloxyarylideneamino)-4,5-dimethyl-1,2,3-triazoles (I, Isoimides) to the isomeric 1-(*N,N*-diarylamino)-4,5-dimethyl-1,2,3-triazoles (II, Imides) (Scheme II).



The results of those studies on the isomerization reaction were considered as evidence in favour of a concerted mechanism.

It is of interest to note that the above mentioned results were gleaned from the study of either identically substituted 1-(α -aroyloxyarylideneamino)-4,5-dimethyl-1,2,3-triazoles (I, where X = Y = H, CH₃O, CH₃, Cl or NO₂) [13] or from the study of 1-(α -benzoyloxyarylideneamino)-4,5-dimethyl-1,2,3-triazoles (I, where X = H, Y = H, CH₃O, CH₃, Cl or NO₂) [14]. However, since in the former case there is a cross-correlation for the influence of the substituents and in the latter the substituent is operating only *via*, a secondary effect in the interacting orbitals, we decided to synthesize and study the thermal isomerization of 1-(α -aroyloxybenzylideneamino)-4,5-dimethyl-1,2,3-triazoles (I, where X = H, CH₃O, CH₃, Cl or CH₃CO and Y = H).

The title compounds Ia-e, with the exception of Ic, were prepared by the reaction of the sodium salt of 1-benzoylamino-3,5-dimethyl-1,2,3-triazole (IV), in dry THF under



kinetically controlled conditions (-50° to -110°), with the appropriately substituted aryl chlorides (Scheme III). Under these conditions the yield of the *N*-acyl products II is either minimized or completely diminished. The unsubstituted isoimide Ic is obtained by the oxidation of biacetyl bis-benzoylhydrazone with lead tetraacetate in chloroform at room temperature [13].

We were unable in spite of our repeated efforts to isolate the *p*-nitro substituted isoimide (I, $X = \text{NO}_2$) even at the lowest temperature employed (-110°) presumably because it rearranged as rapidly as it was formed.

The structure proof of the isoimides Ia-e rests on their spectral and analytical data. Moreover, all of them upon hydrolysis with concentrated hydrochloric acid at room temperature gave the starting benzoylamino-triazole (III).

The kinetic study of the rearrangement of the isoimides to imides was done in *sym*-tetrachloroethane solution (0.15-0.3 *M*) at temperatures 100° , 104.8° and 110° . The rearrangement was followed using ^1H nmr spectroscopy [13]. In particular we measured the rate of disappearance of the 5- CH_3 protons peak in I (at δ 2.35). First order plots were linear to 90% reaction. Rate constants were calculated by the least squares method and the average values are presented in Table I.

Table I

Kinetic Data for the Rearrangement of Isoimides I to Imides II in *sym*-Tetrachloroethane Solution

Substituent X	Temp, $^{\circ}\text{C}$	$10^5 k$, sec^{-1}	$\Delta H^{\#}$, Kcal/mol	$\Delta S^{\#}$, eu
Ia OCH_3	104.8	6.7 ± 0.4		
Ib CH_3	104.8	9.1 ± 0.4		
Ic H	104.8	11.8 ± 0.4	29.2 [a]	-9.2 [a]
Id Cl	100.0	10.0 ± 0.7		
	104.8	15.0 ± 0.4	23.4	-14.6
	110.0	23.4 ± 0.4		
Ie COCH_3	104.8	17.2 ± 0.3		

[a] Taken from ref [11].

As shown by the rate constants in the table, the reaction is accelerated by electron withdrawing groups and retarded by electron donating. A plot of $\log k$ against Hammett's σ values [15] is linear and gives a ρ value of +0.50 (Figure 1). This value may be compared with the ρ of about +0.6 reported by Curtin and Miller [5] and also by Brady and Hegarty [11] for the isomerization of their isoimides to imides and it is consistent with nucleophilic attack (Path 1, Scheme I) as the rate determining step. Our ρ value is rather inconsistent with the *Z*→*E* isomerization as the rate determining step. Actually it seems unreasonably large for an effect of substituents so remote from the site of isomerization; additionally the very fact of it being larger than the value found ($\rho = +0.34$) for substitution in the *p*-position of the aromatic ring directly attached to the C atom of the carbon-nitrogen double bond [14] excludes the possibility for the isomerization to serve as the rate limiting step. The large negative value of $\Delta S^{\#}$ (-14.6 eu) suggests a highly constrained transition state for the rearrangement. This seems compatible not only with the four membered transition state depicted in Path 1 (Scheme I) but also with the concerted mechanism of Path 2. Consequently, the results cannot unambiguously support either pathway.

Our efforts to obtain the *E* isoimides by direct or sensitized photoisomerization of the prevailing in solution *Z* form [16] at room temperature resulted in only high (60%) yields of the imides. The latter implies either that the photochemically produced *E* isomer is converted *via* a fast ground state reaction (Path 1, Scheme I) to the corresponding imide or that the imide is produced directly from the *Z* isoimide in a photochemically allowed [$\pi 2s + \sigma 2s$] process. We favour the second hypothesis since no *E* isomer was found during the irradiation of the isoimides a fact we take as evidence for the fast *E*→*Z* interconversion. However, further experimentation, probably low temperature photochemical studies, is needed to verify this hypothesis.

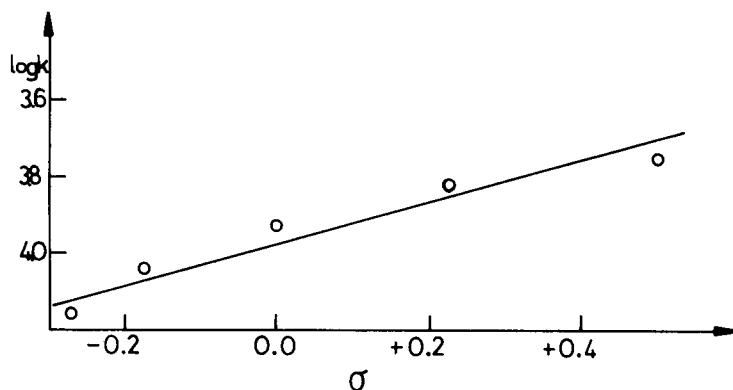


Figure 1. Hammett plot for the thermal isomerization of the isoimides I to imides II.

EXPERIMENTAL

General.

Melting points were determined on a Kofler hot stage apparatus and are uncorrected. The ir spectra were recorded as potassium bromide pellets on a Perkin-Elmer 257 spectrophotometer. Proton nmr spectra were run in deuteriochloroform solution using TMS as internal standard on a Varian A-60A spectrometer. Chemical shifts are quoted in parts per million (s = singlet, d = doublet, q = quartet, m = multiplet). All kinetic measurements were done by the use of a Varian CFT-20 nmr spectrometer. A capillary containing benzene-d₆ was used as an internal field-frequency lock. Mass spectra were recorded on a Hitachi-Perkin Elmer RMU-6L spectrometer at 70 eV. The combustion analyses were performed on a Perkin-Elmer 240 analyzer.

Tetrahydrofuran was distilled immediately before use from lithium aluminum hydride. *Sym*-tetrachloroethane was first washed with saturated solution of potassium carbonate, dried over molecular sieves and fractionally distilled prior to use. The *p*-acetylbenzoyl chloride was prepared by treating *p*-acetylbenzoic acid with thionyl chloride [17].

All reported yields are based on isolated products.

Preparation of the 1-(α -Aroyloxybenzylideneamino)-4,5-dimethyl-1,2,3-triazoles. General Procedure.

With the exception of Ic which was prepared by the lead tetraacetate oxidation of biacetyl bis-benzoylhydrazone [13] the rest of the isoimides were obtained as follows: To 0.01 mole of the amide III dissolved in 15 ml of dry THF 0.02 moles of sodium hydride were added at temperatures ranging from -50° to -110° and the mixture was stirred for 15 minutes. At this temperature, 0.012 mole of the appropriately substituted benzoyl chloride in 15 ml of dry THF were added dropwise with continuous stirring over a period of 15 minutes. The reaction mixture was kept at the low temperature for about 5 hours. The progress of the reaction was monitored by examination of the ir spectrum of aliquots taken from the reaction mixture at various intervals. In particular the end of the reaction could be realized by looking at the disappearance of the carbonyl stretching vibration of the chloride (1750-1780 cm⁻¹).

The reaction mixture was suction filtered and the filtrate evaporated under reduced pressure at room temperature on a rotary evaporator. The resulting sticky (usually orange) oil was crystallized by the addition of small amounts of hexanes and collected on a sintered glass filter.

Further purification of the isoimides by recrystallization from a mixture of chloroform-petroleum ether gave analytically pure products in crystalline form.

1-(α -*p*-Methoxybenzoyloxybenzylideneamino)-4,5-dimethyl-1,2,3-triazole (Ia).

The yield of Ia was 43%, colourless crystals, mp 145-146°; ir (potassium bromide): 1765, 1620, 1524, 1270, 1240, 1060, 1030, 1020, 1013, 844, 744, cm⁻¹; ¹H nmr (deuteriochloroform-TMS): δ 2.20 (s, 4-CH₃), 2.31 (s, 5-CH₃), 3.76 (s, CH₃O-); ms: (70 eV) m/e (relative intensity) 350 (M⁺, 2), 322 (14), 151 (3), 135 (100), 105 (49).

Anal. Calcd. for C₁₉H₁₈N₄O₃: C, 65.13; H, 5.18; N, 15.99. Found: C, 65.19; H, 5.16; N, 16.14.

1-(α -*p*-Methylbenzoyloxybenzylideneamino)-4,5-dimethyl-1,2,3-triazole (Ib).

Compound Ib was obtained in 19% yield as colourless crystals, mp 145-146°; ir (potassium bromide): 1758, 1618, 1272, 1235, 1018, 834, 735 cm⁻¹; ¹H nmr (deuteriochloroform-TMS): δ 2.22 (s, 4-CH₃), 2.36 (s, 5-CH₃), 2.41 (s, *p*-CH₃); ms: (70 eV) m/e (relative intensity) 334 (M⁺, 3), 306 (27), 119 (100), 105 (100).

Anal. Calcd. for C₁₉H₁₈N₄O₂: C, 68.23; H, 5.43; N, 16.76. Found: C, 68.59; H, 5.62; N, 16.93.

1-(α -*p*-Chlorobenzoyloxybenzylideneamino)-4,5-dimethyl-1,2,3-triazole (Id).

Compound Id was obtained in 14% yield as colourless crystals, mp 144-145°; ir (potassium bromide): 1770, 1660, 1615, 1273, 1248, 1096,

1065, 849, 744 cm⁻¹; ¹H nmr (deuteriochloroform-TMS): δ 2.18 (s, 4-CH₃), 2.34 (s, 5-CH₃); ms: (70 eV) m/e (relative intensity) 356 (M⁺ + 2⁺, 2), 354 (M⁺, 3), 326 (15), 141 (100), 139 (59), 111 (25), 105 (40).

Anal. Calcd. for C₁₈H₁₅ClN₄O₂: C, 60.94; H, 4.26; N, 15.79. Found: C, 61.17; H, 4.18; N, 15.82.

1-(α -*p*-Acetylbenzoyloxybenzylideneamino)-4,5-dimethyl-1,2,3-triazole (Ie).

The yield of Ie was 50%, very pale yellow crystals, mp 156-159°; ir (potassium bromide): 1774, 1700, 1660, 1272, 1240, 1070, 770 cm⁻¹; (deuteriochloroform-TMS): δ 2.22 (s, 4-CH₃), 2.35 (s, 5-CH₃), 2.64 (s, CH₃CO-); ms: (70 eV) m/e (relative intensity) 362 (M⁺, 2), 334 (4), 147 (100), 105 (97), 77 (95), 43 (48).

Anal. Calcd. for C₂₀H₁₈N₄O₃: C, 66.28; H, 5.01; N, 15.46. Found: C, 66.30; H, 4.98; N, 15.33.

Preparation of 1-(*N*-Benzoyl-*N*-*p*-acetylbenzoylamino)-4,5-dimethyl-1,2,3-triazole (IIe) via the Thermal Isomerization of Ie.

The isoimide Ie (181 mg, 0.5 mmole) was heated at 160° for about 90 minutes. The resultant crude imide was recrystallized from a mixture of chloroform-petroleum ether to yield 70% of colourless crystals, mp 199-202°; ir (potassium bromide): 1720, 1600, 1265, 1070, 770 cm⁻¹; ¹H nmr (deuteriochloroform-TMS): δ 2.14 (s, 4- and 5-CH₃), 2.57 (s, CH₃CO-); ms: (70 eV) m/e (relative intensity) 362 (M⁺, 0.2), 334 (0.8), 147 (25), 105 (100), 68 (18), 54 (15), 43 (15).

Anal. Calcd. for C₂₀H₁₈N₄O₃: C, 66.28; H, 5.01; N, 15.46. Found: C, 66.25; H, 4.96; N, 15.53.

Attempted Preparation of 1-(α -*p*-Nitrobenzoyloxybenzylideneamino)-4,5-dimethyl-1,2,3-triazole.

Following the general procedure described earlier we isolated only 1-(*N*-benzoyl-*N*-*p*-nitrobenzoylamino)-4,5-dimethyl-1,2,3-triazole in 70% yield. Further attempts to prepare the isoimide via the reaction of the appropriate imidoyl chloride with silver *p*-nitrobenzoate failed to produce any isoimide or imide. The latter was concluded from the lack of the characteristic carbonyl absorptions in the ir spectrum of the resultant reaction mixture.

Attempted *Z*-*E* Isomerization of 1-(α -Benzoyloxybenzylideneamino)-4,5-dimethyl-1,2,3-triazole (Ic).

A solution of 0.32 g (1 mmole) of Ic in 40 ml of degassed dry benzene with/without freshly distilled biacetyl (1 ml, 11.6 mmoles) was irradiated through a pyrex filter with a 400 watt medium pressure mercury-vapour lamp at 20°. Analysis of the reaction mixture by tlc during the irradiation, using more than one solvent mixtures showed only two spots. One for the starting *Z* isoimide and another for the product 1-(*N,N*-dibenzoylamino)-4,5-dimethyl-1,2,3-triazole (IIc) which comes about via a [1,3] benzoyl migration. Removal of the solvent after 3 hours irradiation gave 0.24 g (75%) of the latter in crystalline (mp 98-99°) form.

Kinetic Measurements.

The kinetic study of the isomerization of I to II was conducted at 100°, 104.8° and 110° in *sym*-tetrachloroethane solutions. A solution of I made by dissolving 52 to 101 mg [18] in 1 ml of solvent (0.14 to 0.37 M) was placed in an nmr tube and the latter placed in a thermostated bath. The reaction was monitored, after quenching in cold water, by integration of the sharp 5-CH₃ protons peak in I (~ δ 2.35) at various time intervals. First order plots were linear with correlation coefficients in the region of 0.99.

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