

W. Kehrbach and N. E. Alexandrou

Laboratory of Organic Chemistry, University of Thessaloniki, Greece

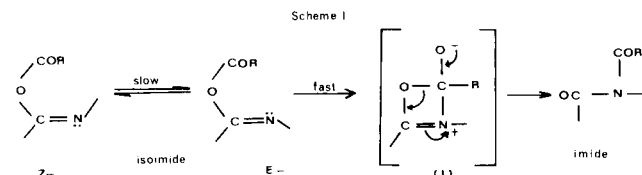
Received January 17, 1978

1-( $\alpha$ -Benzoyloxyarylideneamino)-4,5-dimethyl-1,2,3-triazoles (V) were prepared by reacting the sodium salt of substituted 1-benzoylamino-4,5-dimethyl-1,2,3-triazoles (IV) with benzoyl chloride at  $-50^\circ$ . The uncatalyzed thermal isomerization of isoimides V to the corresponding imides VI was studied kinetically and the reaction mechanism is discussed.

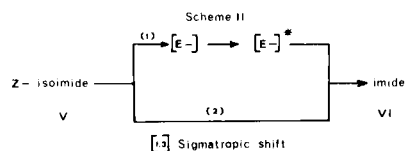
*J. Heterocyclic Chem.*, 15, 1255 (1978)

In our previous work (1) we suggested that the isomerization of the *Z*-configured isoimides II (with the same substituent on both aryls) to imides VI consists of a [1,3] sigmatropic acyl shift. Since there was in this system a cross-correlation for the influence of the substituents, we decided to separate the overall effect and study the rearrangement on the mono-substituted isoimides V, bearing the substituent X only on the C-aryl group. For these isoimides V, few kinetic data are known.

On the other hand, Hegarty and his co-workers (2,3) were recently able to isolate several isoimides in *Z*- and *E*-configuration and to study their interconversion (*Z*, *E*). In respect to the mechanism of isomerization of the isoimides to imides, proceeding through an intramolecular [1,3] acyl migration from oxygen to nitrogen, they suggested (4) a four-membered transition state (I), previously proposed by Curtin and Miller (5), but with *Z*  $\rightarrow$  *E* isomerization as the rate-determining step (Scheme D). However, Hegarty also considered the possibility of a concerted [1,3] sigmatropic acyl shift.



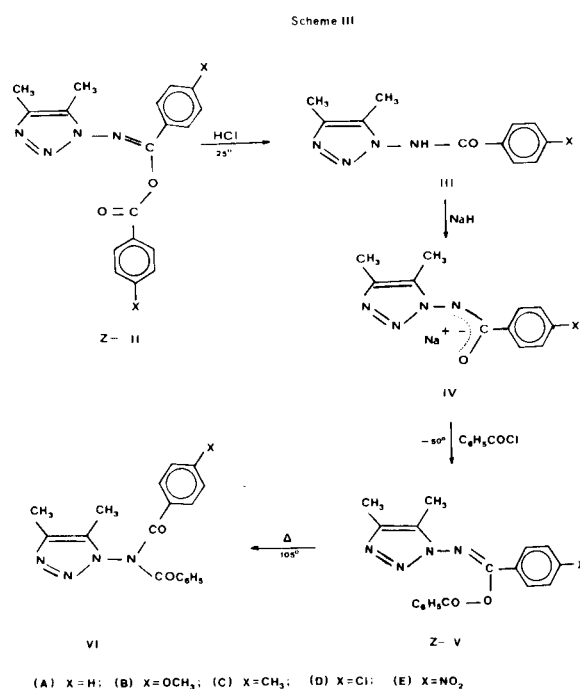
It was hoped therefore, that a kinetic study of the rearrangement of the mono-substituted triazolyloisoimides V might give information on the details of the mechanism. The problem which arises in our case is to choose between two possible path-ways, 1 or 2 (Scheme II).



It is of interest to note that the triazolyloisoimides II exist only in *Z*-configuration in the crystal state (6,7) or in solution (8) and attempts for a photochemical *Z*  $\rightarrow$  *E* conversion of II led to the formation of the corresponding imide along with other decomposition products (9).

The mono-substituted triazolyloisoimides V were pre-

pared by benzoylation at  $-50^\circ$  of the sodium salt of amides IV, which can easily be obtained (10) by acid hydrolysis of the known *bis*-substituted isoimides (1). The sodium salts were obtained by treating the amides with sodium hydride (11) and they probably exist (12) in *Z*-configuration IV (Scheme III). However, direct benzoylation (13) of the amides III leads to isoimides, only when the substituent in the 5-position of the triazole ring is phenyl (9), proving thus that the steric hindrance caused by the phenyl



group favors the formation of *O*-acylated product instead of that of *N*-acylated product.

The unsubstituted isoimide VA obtained by benzoylation of IVA is identical with the *Z*-configured isoimide IIA prepared by oxidation of biacetyl *bis*-benzoylhydrazone (1). Therefore, the *Z*-configuration for the other mono-substituted isoimides (VB-VE) can be assumed.

For the kinetic study of the rearrangement of V to VI we have chosen again nmr spectroscopy (1). The isomerization of the isoimides to imides in *sym*-tetrachloroethane solution (0.15-0.3M) at  $105^\circ$  shows first-order kinetics

Table I

First-order Rate Constants (a) for the Rearrangement of Isoimides V to Imides VI in 1,1,2,2-Tetrachloroethane Solution at 105°

Substituent X	$10^5 k_1, \text{sec}^{-1}$
OCH <sub>3</sub>	9.9
CH <sub>3</sub>	9.95
H	12.4
Cl	13.1
NO <sub>2</sub>	22.0

(a) First-order plots were linear to ~ 90% reaction ( $r$  0.990 to 0.999).

and was followed measuring the rate of disappearance in the nmr spectra of the 5-CH<sub>3</sub> protons peak in V (peak at ~ 2.4  $\delta$ ). The reaction rates  $k_1$  calculated with a least-squares program, with a repeatability  $\pm$  3%, are given in Table I.

From Table I it is seen that the influence of substituents in the C-aryl ring is small, but without any doubt electron-withdrawing groups X increase the rate of isomerization. The Hammett plot is linear (Figure 1) with a  $\rho$  value of + 0.34 ( $r$  0.987 and  $s_b$  (15) 0.031).

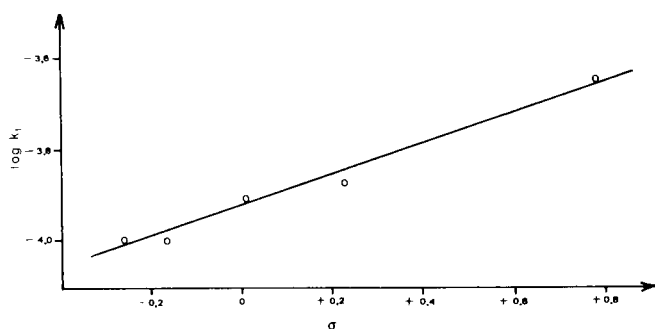


Figure 1. Hammett Plot,  $\text{Log } k_1 (\text{sec}^{-1})$  Versus  $\sigma$  Values (14).

This value is very close to the apparent  $\rho$  value (+ 0.38) found for the rearrangement of *bis*-substituted isoimides (I) with the same substituent X on both the migrating aroyl and the C-aryl group (II). It has been reported (16) that the  $\rho$  value for the E-Z isomerization in several C=N systems lies in the region of + 0.1 to + 0.6. On the other hand, McCarthy and Hegarty (4) have found that the isomerization of E-isoimides to imides with the substituent on the C-aryl group has a  $\rho$  value of -0.49. This value seems compatible with the aspect of formation of a polar intermediate like I. Much more negative  $\rho$  values were found for the influence of the substituents X in the aryl group attached to nitrogen ( $\rho$  -0.91 (4) and -1.27 (17)).

Although the present kinetic data ( $\rho = + 0.34$ ) seem to be in agreement with Hegarty's suggestion (3,4) (reaction-path (1) in Scheme II) and with Z  $\rightarrow$  E isomerization as the rate-determining step, the reaction-path (2) for a syn-

chronous [1,3] sigmatropic benzoyl shift cannot be rigorously excluded, since it is very difficult in this concerted reaction (Figure 2) to predict the influence of substituent X, operating *via* a secondary effect in the interacting orbitals.

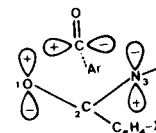


Figure 2. Interacting Orbitals ( $\phi_2, p$ ) in [1,3] Sigmatropic Benzoyl Shift. Suprafacial Process with Inversion of the Migrating Group [ $\pi 2s + \sigma 2a$ ].

In several cases, on the other hand, quite different  $\rho$  values from those mentioned above have been reported. Thus, Gozlan, *et al.* (18), have found recently a negative effect for the influence of the substituent X in Z  $\rightarrow$  E isomerization of benzamidoximes (X-aryl substituted),  $\rho$  being -0.56. Furthermore, the activation entropy associated with Z  $\rightarrow$  E isomerization in C=N systems lies in general (16) in the region of  $\Delta S^*$  from -3.6 to +3.4 e.u., whereas for the isomerization of isoimides II a more negative value ( $\Delta S^*$  -9.2 e.u.) was found (1), which is in better agreement with the aspect of a pericyclic transition state.

In conclusion, it is evident that more work is required for a definite decision on what mechanism operates and the problem is under further consideration.

The analytical and the main spectroscopic data for all new compounds are given in Tables II, III and IV.

## EXPERIMENTAL

All melting points are uncorrected and they were obtained with a Kofler hot stage apparatus. Uv spectra were obtained with a Unicam Model SP 8000 spectrophotometer, ir spectra with a Perkin-Elmer Model 257, whereas nmr spectra reported in  $\delta$  units with a Varian Associates A-60A spectrometer with TMS as internal reference. The mass spectra were obtained with a Hitachi-Perkin-Elmer Model RMU-6L spectrometer with ionization energy 70 eV. Analyses were performed with a Perkin-Elmer Model 240 CHN analyzer.

1-( $\alpha$ -Aroyloxyarylideneamino)-4,5-dimethyl-1,2,3-triazoles (II) obtained by oxidation of biacetyl bis-aryloxyhydrazones with lead tetraacetate were identical with those previously described (1).

Preparation of the 1-(N-Aroylamino)-4,5-dimethyl-1,2,3-triazoles (III).

According to a general procedure (9,19) these compounds were obtained by treating at room temperature 1 g. of isoimide II with 12 ml. of concentrated hydrochloric acid. After 30 minutes the reaction mixture was neutralized with 20% sodium carbonate solution and extracted with methylenechloride. Evaporation of the solvent gave the amide III which is recrystallized from a mixture of water-ethanol (Table II).

Under these conditions the isoimide IIE was stable to acid hydrolysis, therefore the *p*-nitrobenzamide IIIE was prepared by

Table II

Analytical Data for the 1-(*N*-Aroylamino)-4,5-dimethyl-1,2,3-triazoles (III)  
Obtained from Acid-Hydrolysis of the Isoimides (II)

Compound	M.p. °C	Yield	Ir $\nu_{C=O}$ , $cm^{-1}$ (Nujol)	Uv nm (log $\epsilon$ ) (Methanol)	Nmr $\delta$ CH <sub>3</sub> (Deuteriochloroform)	Ms m/e (R.I. %)	Formula	Mol. Weight	Calcd. C H N	Analysis % C H N	Found C H N
IIIB	179	90	1662	259 (4.16)	2.16 [3] s 2.18 [3] s	M <sup>+</sup> 246 (18) 218 (35) 135 (100) 68 (29) 54 (42)	C <sub>12</sub> H <sub>14</sub> N <sub>4</sub> O <sub>2</sub>	246.3	58.53 5.73 22.75	58.17 5.76 22.78	58.17 5.76 22.78
IIIC	91-94	95	1669	239 (4.14)	2.15 [3] s 2.18 [3] s 2.41 [3] s (a)	M <sup>+</sup> 18 <sup>+</sup> 230 (6) 202 (14) 119 (100) 68 (25) 54 (11)	C <sub>12</sub> H <sub>14</sub> N <sub>4</sub> O·H <sub>2</sub> O (b)	248.3	58.05 6.50 22.57	58.24 6.49 22.68	6.49 22.68
IIID	146-147	96	1681	238 (4.17)	2.13 [6] s	M <sup>+</sup> 18 <sup>+</sup> 252 (4) 250 (11) 222 (14) 139 (100) 68 (50) 54 (6)	C <sub>11</sub> H <sub>11</sub> ClN <sub>4</sub> O·H <sub>2</sub> O (b)	268.7	49.17 4.88 20.85	49.07 5.05 20.95	5.05 20.95
IIIE	199	91	1678	261 (3.90)	2.26 [6] s	M <sup>+</sup> 261 (8) 233 (18) 150 (100) 68 (95) 54 (46)	C <sub>11</sub> H <sub>11</sub> N <sub>5</sub> O <sub>3</sub>	261.3	50.57 4.24 26.81	50.56 4.27 26.83	4.27 26.83

(a) C<sub>6</sub>H<sub>4</sub>-CH<sub>3</sub> (-p). (b) Monohydrate.

Table III

Analytical Data for the 1-( $\alpha$ -Benzoyloxyarylideneamino)-4,5-dimethyl-1,2,3-triazoles (V)  
Obtained from Benzoylation of (IV)

Compound	M.p. °C	Yield	Ir $\nu_{C=O}$ , $cm^{-1}$ (Nujol)	Uv nm (log $\epsilon$ ) (Methanol)	Nmr $\delta$ CH <sub>3</sub> (Deuteriochloroform)	Ms m/e (R.I. %)	Formula	Mol. Weight	Calcd. C H N	Analysis % C H N	Found C H N
VB	137	30	1742	233 (3.87) 304 (4.06)	2.23 [3] s 2.35 [3] s	M <sup>+</sup> 350 (3) 322 (9), 135 (100) 133 (7), 122 (2) 105 (79)	C <sub>19</sub> H <sub>18</sub> N <sub>4</sub> O <sub>3</sub>	350.4	65.13 5.18 15.99	65.24 5.25 16.05	5.25 16.05
VC	139	54	1745	241 (4.15) 286 (4.21)	2.23 [3] s 2.36 [3] s (a) 2.42 [3] s	M <sup>+</sup> 334 (4) 306 (17), 119 (100) 105 (100)	C <sub>19</sub> H <sub>18</sub> N <sub>4</sub> O <sub>2</sub>	334.4	68.23 5.43 16.76	68.17 5.48 16.82	5.48 16.82
VD	154	53	1735	243 (4.19) 283 (4.25)	2.22 [3] s 2.34 [3] s	M <sup>+</sup> 356 (1) 354 (3), 326 (7) 139 (67), 137 (6) 122 (3), 105 (100)	C <sub>18</sub> H <sub>15</sub> ClN <sub>4</sub> O <sub>2</sub>	354.8	60.94 4.26 15.79	60.38 4.44 15.61	4.44 15.61
VE	163-164	8	1745	237 (4.24) 295 (4.21)	2.29 [3] s 2.42 [3] s	M <sup>+</sup> 365 (0.6) 337 (3), 150 (14) 148 (4), 120 (4) 105 (100)	C <sub>18</sub> H <sub>15</sub> N <sub>5</sub> O <sub>4</sub>	365.4	59.18 4.14 19.17	58.81 4.15 19.08	4.15 19.08

(a) C<sub>6</sub>H<sub>4</sub>-CH<sub>3</sub> (-p).

Table IV  
Analytical Data for the 1-(N-Benzoyl-N-aryl-amino)-4,5-dimethyl-1,2,3-triazoles (VI)  
Obtained from Isomerization of the Isoimides (V)

Compound	M.p. °C	Yield	Ir $\nu$ C=O, $\text{cm}^{-1}$ (Nujol)	Uv nm (log $\epsilon$ ) (Methanol)	Nmr $\delta$ CH <sub>3</sub> (Deuteriochloroform)	Ms m/e (R.I. %)	Formula	Mol. Weight	Caled.		Analysis %		Found	
									C	H	N	C	H	N
VIB	115	85	1716	240 (4.26) 290 (4.23)	2.17 [3] s 2.25 [3] s	M <sup>+</sup> 350 (0.7) 322 (15), 135 (100) 105 (45), 68 (3) 54 (4)	C <sub>19</sub> H <sub>18</sub> N <sub>4</sub> O <sub>3</sub>	350.4	65.13	5.18	15.99	65.07	5.15	15.91
VIC	161	95	1710	253 (4.18)	2.15 [3] s 2.24 [3] s 2.39 [3] s (a)	M <sup>+</sup> 334 (0.2) 306 (14), 119 (100) 105 (67), 68 (5) 54 (2)	C <sub>19</sub> H <sub>18</sub> N <sub>4</sub> O <sub>2</sub>	334.4	68.23	5.43	16.76	68.40	5.55	16.55
VID	110-112	90	1719	247 (4.24)	2.15 [3] s 2.25 [3] s	M <sup>+</sup> 356 (0.2) 354 (0.6), 326 (24) 139 (89), 105 (100) 68 (23), 54 (4)	C <sub>18</sub> H <sub>15</sub> ClN <sub>4</sub> O <sub>2</sub>	354.8	60.94	4.26	15.79	60.91	4.31	15.76
VIE	149-153	90	1720	252 (4.24)	2.16 [3] s 2.24 [3] s	M <sup>+</sup> 365 (0.4) 337 (12), 150 (50) 105 (100), 68 (18) 54 (12)	C <sub>18</sub> H <sub>15</sub> N <sub>5</sub> O <sub>4</sub>	365.4	59.18	4.14	19.17	59.07	4.15	19.14

(a) C<sub>6</sub>H<sub>5</sub>-CH<sub>3</sub> (-p).

reacting the 1-amino-1,2,3-triazole with *p*-nitrobenzoylchloride in tetrahydrofuran (THF) solution in the presence of pyridine.

Preparation of 1-( $\alpha$ -Benzoyloxyarylideneamino)-4,5-dimethyl-1,2,3-triazoles (V).

A general procedure is described. To 1 mmole of benzamide III dissolved in 3 ml. of dry THF 1.1 mmoles of sodium hydride were added at -50° and the mixture was stirred for 15 minutes. At this temperature, 1.2 mmoles of benzoylchloride in 1 ml. of THF were added slowly and stirred for 1 hour. The reaction mixture was then poured into 10 ml. of phosphate buffer (pH = 7) and 10 ml. of iced-water, and extracted with ether.

The isoimides V were obtained upon evaporation of the ether and recrystallized from a mixture of ethyl acetate-light petroleum ether (Table III).

Thermal Rearrangement of Isoimides V to 1-(N-Benzoyl-N-aryl-amino)-4,5-dimethyl-1,2,3-triazoles (VI).

The rearrangement proceeds almost in quantitative yield by heating the isoimide V at 150° for 90 minutes. The products VI are recrystallized from a mixture of ethyl acetate-petroleum ether (Table IV).

Kinetic Measurements.

The method used for the kinetics of isomerization of V to VI was the same with that previously described (1). The rate of isomerization of the isoimides in *sym*-tetrachloroethane solution at 105 ± 0.05° was followed using nmr spectroscopy and by measuring the disappearance of the 5-CH<sub>3</sub> protons peak. First-order plots were linear to about 90% reaction. The correlation coefficient *r* for the line was in the range of 0.999, except for VIC where *r* was 0.990. The repeatability in rate constants was ± 3%; the rates *k*<sub>1</sub> were calculated with a Hewlett-Packard Model 9001 calculator, with a least-squares program.

In cases where there was a limited amount of isoimide the rate was measured using only one nmr tube. At fixed time intervals the reaction was stopped by immersing the tube in liquid nitrogen. Then the tube was placed in the nmr probe for measurement and afterwards it was placed again into the thermostated bath and the reaction was continued. A control experiment showed that the difference in *k*<sub>1</sub> between the two methods was less than ± 3%.

Acknowledgements.

We are grateful to the "Dr. Carl Duisberg-Stiftung" for a grant to W. K. and to the National Hellenic Research Foundation for financial support of this work. We also wish to thank Professor E. Winterfeldt for some analyses, which were made in the Institut für Organische Chemie der Technischen Universität, Hannover.

## REFERENCES AND NOTES

- (1) N. E. Alexandrou and C. P. Hadjiantoniou, *J. Heterocyclic Chem.*, **14**, 269 (1977).
- (2) M. T. McCormack and A. F. Hegarty, *J. Chem. Soc., Perkin Trans. II*, 1701 (1976).
- (3) D. G. McCarthy and A. F. Hegarty, *ibid.*, 1080 (1977).
- (4) D. G. McCarthy and A. F. Hegarty, *ibid.*, 1085 (1977).
- (5) D. Y. Curtin and L. L. Miller, *J. Am. Chem. Soc.*, **89**, 637 (1967).
- (6) H. Bauer, A. J. Boulton, W. Fedeli, A. R. Katritzky, A. Majid-Hamid, F. Mazza and A. Vaciego, *J. Chem. Soc., Perkin Trans. II*, 662 (1972).
- (7) S. C. Kokkou and P. J. Rentzeperis, *Acta Cryst.*, **B31**, 1564 (1975).

- (8) N. A. Rodios and N. E. Alexandrou, *J. Chem. Soc., Perkin Trans. II*, 1779 (1977).
- (9) C. P. Hadjiantoniou, Ph. D. Thesis, University of Thessaloniki, 1975.
- (10) D. Y. Curtin and N. E. Alexandrou, *Tetrahedron*, **19**, 1967 (1963).
- (11) D. Y. Curtin and J. H. Engelman, *J. Org. Chem.*, **37**, 3439 (1972).
- (12) M. E. Jung and T. J. Shaw, *Tetrahedron Letters*, 3305 (1977).
- (13) H. El Khadem, M. A. E. Shaban and M. A. M. Nassr, *J. Chem. Soc. C*, 2167 (1970).
- (14) D. H. McDaniel and H. C. Brown, *J. Org. Chem.*, **23**, 420 (1958).
- (15) W. H. Davis, Jr. and W. A. Pryor, *J. Chem. Educ.*, **53**, 285 (1976).
- (16) C. G. McCarty in "The Chemistry of the Carbon-Nitrogen Double Bond", S. Patai, Ed., John Wiley and Sons, New York, N. Y., 1970, Chapter 9.
- (17) J. S. P. Schwarz, *J. Org. Chem.*, **37**, 2906 (1972).
- (18) H. Gozlan, R. Michelot, C. Riche and R. Rips, *Tetrahedron*, **33**, 2535 (1977).
- (19) H. V. Pechmann and W. Bawer, *Ber.*, **42**, 659 (1909); R. Stollé, *ibid.*, **59**, 1743 (1926).