

Studies on the Decarboxylation Reactions. Note II (1).
Kinetic Study of the Decarboxylation Reaction of 5-Amino-1,3,4-thiadiazole-2-carboxylic Acid (I) to 2-Amino-1,3,4-thiadiazole (III).

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The rate constants of the decarboxylation reaction in water of 5-amino-1,3,4-thiadiazole-2-carboxylic acid (I) to 2-amino-1,3,4-thiadiazole (III) over the pH range 0.25-3.91 have been measured and the activation parameters determined. The results obtained have been compared with previous results on the decarboxylation of 5-amino-1,3,4-oxadiazole-2-carboxylic acid (II) to gain information on the mechanism of the reaction studied.

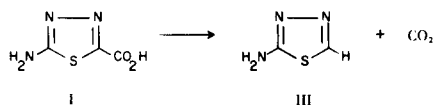
J. Heterocyclic Chem., 14, 309 (1977).

Continuing our researches (1) on decarboxylation reactions of heteroaromatic acids we report, in this paper, kinetic data on the behaviour of 5-amino-1,3,4-thiadiazole-2-carboxylic acid (I).

These data compared with our previous results (1) on the decarboxylation of 5-amino-1,3,4-oxadiazole-2-carboxylic acid (II) give useful information about the influence of the nature of the heterocyclic ring on reactivity and reaction mechanism (2).

Products

Compound I decarboxylates to 2-amino-1,3,4-thiadiazole (III) in water in high yield.



Kinetic Data

The apparent first-order kinetic constants at various proton activities over the pH range 0.25-3.91 and the activation parameters are collected in Table I. A plot of kinetic constants *versus* pH shows that the decarboxylation rate is strongly affected by the proton activity and gives the expected bell-shaped curve (3) (Figure). Also the concentrations of the present species (H_2A^+ , N, and A^-) are dependent on pH (4); thus, the ampholite concentration, calculated through the K_1 and K_2 values determined by us (Table II), presents a trend (Figure) similar to that of the apparent kinetic constant.

Kinetic data have been handled as indicated in a

previous paper (1). The k^* values obtained by the least square treatment of the following equation:

$$\log k_{\text{obs}} \frac{[\text{H}^+]^2 + K_1 [\text{H}^+] + K_1 K_2}{K_1} = \log k^* + \log [\text{H}^+]$$

and the related activation parameters are set forth in Table III.

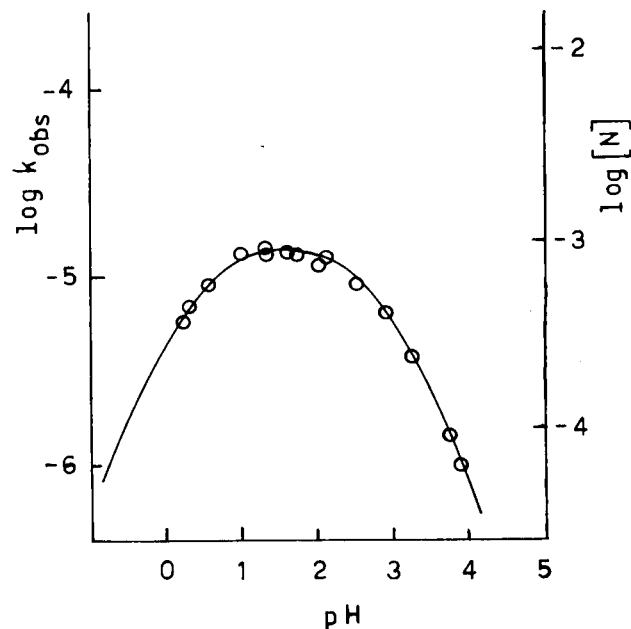


Figure: Open circles refer to the plot of $\log k_{\text{obs}}$ at 40° *versus* proton activity. The curve is calculated for $\log [N]$ *versus* proton activity as indicated in reference (1).

Table 1

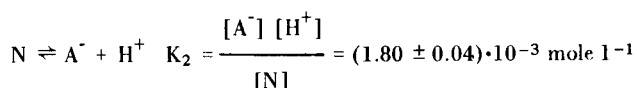
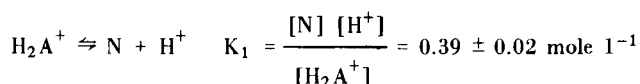
Apparent Rate Constants and Activation Parameters for the Decarboxylation Reaction of I (a) to III (a) in Water

Buffers (b)	pH (c)	10 ⁵ k, sec ⁻¹ , at various temperatures (°C) (d)			ΔH [‡] (e) kcal mole ⁻¹	ΔS [‡] (f) u.e.
A	0.25	0.591 (40.1)	3.16 (51.3)	11.8 (60.2)	30.9	14.0
A	0.32	0.699 (39.8)	3.59 (51.2)	15.0 (60.3)	30.9	14.5
A	0.61	0.912 (39.8)	5.06 (51.2)	20.6 (60.3)	31.5	16.9
A	1.00	1.41 (40.6)	6.69 (51.1)	24.7 (60.3)	30.0	12.8
A	1.32	1.52 (40.6)	7.83 (51.1)	27.5 (60.2)	30.3	15.4
B	1.36	1.34 (40.1)	6.83 (50.6)	25.7 (59.9)	30.9	15.9
A	1.61	1.62 (41.2)	7.27 (51.2)	26.2 (60.3)	30.3	14.0
A	1.76	1.32 (40.1)	7.15 (51.3)	25.2 (60.2)	30.5	14.3
A	2.03	1.08 (39.8)	6.66 (51.1)	24.0 (60.3)	31.5	17.2
B	2.16	1.28 (40.1)	5.83 (50.6)	22.3 (59.9)	29.9	12.4
B	2.52	0.936 (40.1)	4.48 (50.6)	16.9 (59.9)	30.3	13.1
B	2.88	0.642 (40.1)	3.02 (50.6)	11.2 (59.9)	29.9	11.2
B	3.23	0.381 (40.1)	1.76 (50.6)	6.57 (60.0)	29.7	9.3
B	3.73	0.141 (40.1)	0.656 (50.6)	2.46 (60.0)	29.8	7.7
B	3.91	0.104 (40.1)	0.442 (50.6)	1.69 (60.0)	29.0	4.6

(a) I and III were prepared and purified as described in the literature (6). (b) Buffers: A, hydrochloric acid; B, hydrochloric acid and sodium citrate. (c) pH Measurements were made as previously described (1). (d) The rate constants are accurate to better than ± 3%; the kinetics were followed spectrophotometrically by measuring the disappearance of I at 280 nm as previously described (1). (e) At 40°, the maximum error is 0.6 kcal/mol⁻¹. (f) At 40°.

Table II

Ionization Constants (a) Related to Equilibria Between Conjugated Acid (H₂A⁺), Conjugated Base (A⁻) and Ampholite (N) (b) for I (c).



(a) Determined at 20° spectrophotometrically according to Leggate and Dunn (5). Absorbance measurements were made at nm 280. Constants were determined at ionic strength 1.0.

(b) Ampholite concentration [N] is equal to the sum of concentrations of aminocarboxylic acid form [HA] and zwitterionic form [Z] and is independent of proton activity.

(c) The corresponding data for II are K₁ = 1.36 ± 0.05 mole l⁻¹ and K₂ = (3.25 ± 0.20) · 10⁻² mole l⁻¹.

Discussion of Results

In order to make a comparison between the behaviour in the decarboxylation reaction of I and II some data relative to II have also been reported in Tables II and III. One can observe that K₁ and K₂ values for compound I are lower than those measured for II according to the

expected influence of sulphur and oxygen heteroatoms on the acidity constants. Moreover, the kinetic data obtained for I parallel those of II pointing out that in both cases the same decarboxyprotonation mechanism is operating. On the other hand, at each proton activity, the decarboxylation rate of I is lower than that of II and also calculated k* values follow the same pattern.

An examination of the activation parameters shows that this fact is essentially determined by a change in activation enthalpies.

These findings are in good agreement with the decarboxyprotonation mechanism proposed by us for the decarboxylation of II but cannot exclude that protodecarboxylation is also operating. In fact, the different aromatic character of the two ring favours decarboxylation of II, moreover the oxygen heteroatom is able to accommodate a negative charge better than sulphur and then also to favour decarboxyprotonation; on the other hand the 1,3,4-oxadiazole ring should be more prone (7) to receive electrophilic attack than 1,3,4-thiadiazole ring and then to favour the protodecarboxylation.

REFERENCES AND NOTES

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Table III

Rate Constants (k^*) Calculated and Activation Parameters Related

Studied Reaction	$10^5 k^*$, sec ⁻¹ , at various temperatures (°C)			ΔH^\ddagger (a)	ΔS^\ddagger (a)
				kcal mole ⁻¹	u.e.
I → III	1.48 (40.0) (b)	7.05 (50.0) (c)	30.2 (60.0) (d)	30.6	17.1
II → IV (e)	28.0 (40.0)	115. (50.0)	426. (60.0)	27.6	13.3

(a) At 40°. (b) Slope 1.00 ± 0.01 , $i \equiv \log k^* -4.83 \pm 0.02$, $r 0.9996$, $n 15$, $t_s 97.5$, $t_i 212.2$, C.L. > 99.9%. (c) Slope 1.01 ± 0.01 , $i \equiv \log k^* -4.15 \pm 0.02$, $r 0.9997$, $n 15$, $t_s 139.3$, $t_i 258$, C.L. > 99.9%. (d) Slope 1.02 ± 0.01 , $i \equiv \log k^* -3.52 \pm 0.02$, $r 0.9998$, $n 15$, $t_s 140.5$, $t_i 218.7$, C.L. > 99.9%. (e) Data from reference (1).

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(7) Quantitative studies on electrophilic substitutions of 1,3,4-oxadiazole and 1,3,4-thiadiazole derivatives are lacking, but we suggest that 1,3,4-oxadiazole should be more reactive than 1,3,4-thiadiazole by analogy with the pair furan-thiophene.