prior to cooling. Unreacted diene and solvent were then evaporated through tared connections to a series of two tared Dry Ice cooled traps at a pressure of 0.5 to 20 mm., depending on the diene, the bottle being warmed to 25–40°. This was continued until the loss in weight of the bottle equalled the gain in weight of the connections to the traps. The condensate in the first trap was evaporated at reduced pressure to give a small residue. The reacted diene was considered to be this residue plus the condensate in the connections plus the weight of reaction mixture in the bottle minus the starting maleic anhydride minus the antioxidant (if any) minus the increase in weight of the insert. Corrections for diene reacted during the evaporation were necessary only in the cases of 2-neopentylbutadiene and cyclopentadiene; they amounted to 1 to 6% for the neopentyl derivative and 10 to 15% for cyclopentadiene.

Acknowledgment.—The authors thank Dr. Paul D. Bartlett for several discussions concerning the interpretation of the results in this paper.

[CONTRIBUTION FROM THE RESEARCH INSTITUTE FOR MEDICINE AND CHEMISTRY, CAMBRIDGE 42, MASS.]

Intramolecular Assistance of Decarboxylative Acylation

BY PHILIP A. CRUICKSHANK AND JOHN C. SHEEHAN

RECEIVED JANUARY 27, 1961

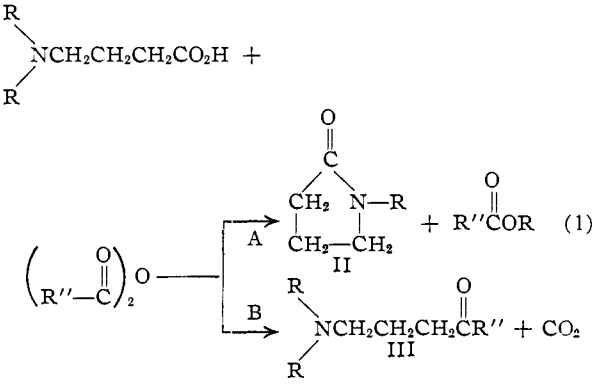
Simple γ- and δ-dialkylamino acids unsubstituted at the α-position and having primary alkyl substituents on nitrogen have been found to react with carboxylic acid anhydrides to afford γ- and δ-dialkylamino ketones. When the substituents on nitrogen are secondary alkyl or benzyl the reaction takes a different course, affording lactams and alkyl esters.

Intramolecular interactions between functional groups in a molecule frequently will lead to reactions which take place with difficulty, if at all, when the interactions are of an intermolecular nature. We wish to report some new reactions of γ- and δ-dialkylamino acids with carboxylic acid anhydrides due presumably to intramolecular interactions of the carboxyl and tertiary amine groups. The reactions observed are a decarboxylative acylation to afford γ- or δ-dialkylamino ketones and/or carbon–nitrogen cleavage to afford lactams and alkyl esters. These reactions are not normally encountered in mixtures of simple carboxylic acids, carboxylic acid anhydrides and tertiary amines.

Intramolecular reactions of γ- and δ-dialkylamino acids have been observed previously.[1–5] Acid chlorides of these compounds when heated afford pyrrolidones and piperidones, respectively, as well as one equivalent of alkyl chloride.[1,2] This reaction appears to be general when run under the proper conditions, *e.g.*, use of phosphorus trichloride to form the acid chloride followed by heating the solid product to 160° or higher.[2] Thionyl chloride could be used if the dialkylamino acid was free of α-hydrogen; if not, sulfurous products predominated. Pyrolysis of γ-dialkylamino acids[3,4] and of their corresponding "betaines"[5] was shown to give γ-lactones and the secondary or tertiary amines.

During an investigation of the chemistry of 18-substituted solanidane alkaloids (isorubijervine derivatives) it was observed that solanidane-18-oic acids reacted with acetic anhydride to afford neutral products.[6] These neutral compounds were shown to be "acetoxy-lactams" formed by attack of the carboxyl carbonyl on the nitrogen atom with concomitant cleavage of the C(16)-N bond and introduction of an acetoxy group at C(16). In order to determine whether this lactam-forming reaction was general, several simple γ-dialkylaminobutyric acids and a δ-dialkylaminovaleric acid were investigated in respect to reactions with carboxylic acid anhydrides.

The reaction was first studied with simple γ-dialkylamino derivatives of butyric acid (I). The nature of the principal products of the reaction between these acids and the anhydrides was found to be dependent upon the type of alkyl group substituted on the nitrogen. With secondary alkyl substituents, *e.g.*, γ-(N,N-dicyclohexylamino)-butyric acid, or benzyl substituents, γ-(N,N-dibenzylamino)-butyric acid, the expected pyrrolidone II and secondary alkyl or benzyl ester were formed (eq. I, path A). However, when both



nitrogen substituents were primary alkyl, *e.g.*, γ-(1-piperidino)-butyric acid, an unexpected reaction resulted, formation of a γ-dialkylamino ketone (III; eq. I, path B). This ketone was formed by incorporation of an acyl group from the anhydride and loss of carbon dioxide. In the one instance in which a mixed dialkylamino group was investigated, γ-(N-methyl-N-benzylamino)-butyric acid, both lactam and ketone were formed with the former predominating. Ketone also was formed when the nitrogen was substituted with a secondary alkyl group in the acid chain, γ-(4-morpholino)-valeric

(1) J. H. Gardner, N. R. Easton and J. R. Stevens, *J. Am. Chem. Soc.*, **70**, 2906 (1948).

(2) R. L. Clarke, A. Mooradian, P. Lucas and T. J. Slauson, *ibid.*, **71**, 2821 (1949).

(3) H. R. LeSuer, *J. Chem. Soc.*, **95**, 273 (1909); **97**, 173 (1910).

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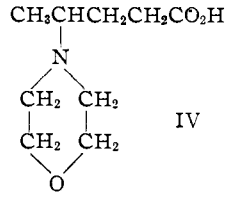


IV

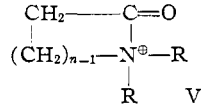
acid (IV); although carbon–nitrogen cleavage may also have occurred, the expected 4-(γ-acetoxyvaleryl)-morpholine could not be isolated. When ketones were obtained as the major products the yields were 47–65%; lactams were obtained in 66–85% yields. A summary of the products obtained from nine γ-dialkylamino acids with two anhydrides is given in Table III.

Only one example of a δ-dialkylamino acid was investigated. Treatment of δ-(N,N-dimethylamino)-valeric acid with acetic anhydride afforded 6-(N,N-dimethylamino)-hexan-2-one in 42% yield. Although not ascertained experimentally, formation of piperidones would be expected with δ-dialkylamino acids having benzyl or secondary alkyl substituents on nitrogen.

Preparation of ketones by acylation of carboxylic acids in general requires additional activation of the α-methylene group.[7] Mixtures of phenylacetic acid, acetic anhydride and a base gave methyl benzyl ketone and dibenzyl ketone as products; it was demonstrated that anhydride molecules acted as both acceptor and addendum in this reaction. Upon removal of the activating phenyl substituent to the β-carbon atom, as in hydrocinnamic acid, the acylation reaction was prevented and a mixture of carboxylic acid anhydrides was obtained.

In our hands a mixture containing equimolar quantities of butyric acid and N-ethylpiperidine dissolved in an excess of acetic anhydride gave a 3% yield of carbon dioxide (as barium carbonate) during 3 hours of heating under reflux. A similar yield of carbon dioxide was obtained when only N-ethylpiperidine and acetic anhydride were heated. Base-catalyzed decarboxylative acylation of simple aliphatic carboxylic acids (as the anhydride) therefore may take place, but to a negligible extent when compared to the reactions of the dialkylamino acids.

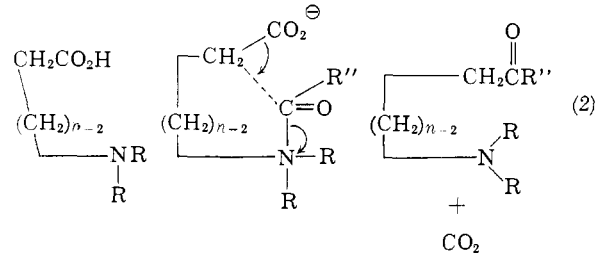
It has been suggested that formation of lactams from γ- and δ-dialkylamino acid chlorides involves a transitory quaternary amide (V).[2] An intermediate such as this can also be used to explain the formation of both lactams and ketones from the γ- or δ-dialkylamino acids and carboxylic acid anhydrides. Activation of the α-methylene group in V could be explained by an inductive effect of



V

the strongly polar nitrogen through the easily polarizable carbonyl group. With primary alkyl substituents on nitrogen, acylation would take place at this position, followed by ring opening and decarboxylation to afford the dialkylamino ketone. When the alkyl substituents on nitrogen could form more stable carbonium ions (secondary alkyl or benzyl) the intermediate would convert preferentially to lactam by elimination of one of these groups.

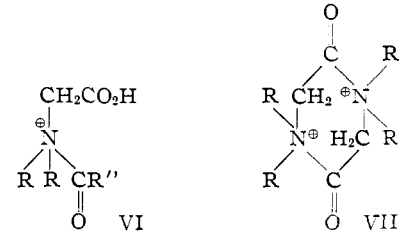
An alternative mechanism for ketone formation is shown in eq. 2. In this case the quaternary amide intermediate would supply the acylating



(2)

group, with driving force for the reaction being supplied by loss of carbon dioxide. This scheme appears less satisfactory, however, since it cannot accommodate lactam formation.

The reaction of α-amino acids with carboxylic acid anhydrides in the presence of a base proceeds smoothly to give α-acylamino ketones (Dakin-West reaction).[8,9] It has been suggested that this reaction proceeds *via* an intermediate oxazolone containing an active α-hydrogen.[9] A reaction also readily takes place between α-dialkylamino acids and carboxylic acid anhydrides affording N,N-dialkylamides and polymers, presumably *via* an intermediate α-dialkylamino ketone.[10] In this case the oxazolone mechanism cannot be accommodated; a quaternary amide species such as VI or VII is likely to be the intermediate undergoing acylation.



VI VII

Syntheses of δ-dialkylamino ketones have been reported by condensation of δ-bromoketones and dialkyl amines[11]; the δ-bromoketones are readily prepared by condensation of α,γ-dibromoalkanes with acetoacetic ester. Syntheses of γ-dialkylamino ketones have been reported by condensation of α-halo dialkylaminoalkanes with β-keto esters.[12] These procedures are more general than the decarboxylative acylation of γ- and δ-dialkylamino acids, but the latter when applicable frequently offers the advantages of easily obtainable starting materials and of an easily manipulated reaction.

The γ- and δ-dialkylamino acids, isolated as hydrochloride salts (Table II), were prepared by

(7) J. A. King and F. H. McMillan, *J. Am. Chem. Soc.*, **73**, 4911 (1951).

(8) H. O. Dakin and R. West, *J. Biol. Chem.*, **78**, 91, 745, 757 (1928).

(9) G. H. Cleland and C. Niemann, *J. Am. Chem. Soc.*, **71**, 841 (1949).

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(11) E. P. Anderson, J. V. Crawford and M. L. Sherrill, *ibid.*, **68**, 1294 (1946).

(12) P. C. Guha and S. P. Mukherji, *Current Sci.*, **12**, 148 (1943).

TABLE I

METHYL ω-DIALKYLAMINOBUTYRATES $R_2N(CH_2)_3CO_2CH_3$

R₂N–	Yield, %	B.p. °C.	Mm.	n_D	t, °C.	Empirical formula	Carbon, % Calcd.	Carbon, % Found	Hydrogen, % Calcd.	Hydrogen, % Found	Nitrogen, % Calcd.	Nitrogen, % Found
Piperidino-	98	99–100	9	1.4578	24	$C_{10}H_{19}NO_2$	64.83	65.51	10.34	10.29	7.56	7.80
Morpholino-	95	90–92	1.5	1.4582	22	$C_9H_{17}NO_3$	57.73	58.10	9.15	9.21	7.48	7.67
N-Methylbenzylamino-[a]	82	114–115	0.75	1.5068	22	$C_{13}H_{19}NO_2$	70.55	70.94	8.65	8.66	6.33	6.58
Dibenzylamino-[a]	76	164–166	.56	1.5436	25	$C_{19}H_{23}NO_2$	76.73	77.04	7.79	7.66	4.71	5.24
Dicyclohexylamino-[a]	82	145–152	.9[c]	....	..	$C_{17}H_{31}NO_2$	72.55	72.87	11.10	10.60	4.98	4.96
Diethylamino-[b]	92	82–83	12	1.4392	26	.....	...	...	...	...	..	..
Di-*n*-propylamino-	88	95–101	7	1.4348	24	$C_{11}H_{23}NO_2$	...	...	...	...	6.96	6.90
Diisopropylamino-[a]	76	66–70	1	1.4385	24	$C_{11}H_{23}NO_2$	...	...	...	...	6.96	6.54

[a] Toluene heated under reflux as reaction medium. [b] Reported[13] b.p. 63° (3 mm.). [c] M.p. 55–56.5°; recrystallized from acetone–water.

TABLE II

ω-DIALKYLAMINO ACID HYDROCHLORIDES $R_2N(CH_2)_nCO_2H\cdot HCl$

R₂N–	n	Yield, %	M.p., °C.	Crystn. solvent[c]	Empirical formula	Carbon, % Calcd.	Carbon, % Found	Hydrogen, % Calcd.	Hydrogen, % Found	Nitrogen, % Calcd.	Nitrogen, % Found	Chlorine, % Calcd.	Chlorine, % Found
Piperidino-	3	94	190–192	A	$C_9H_{18}ClNO_2$	52.04	51.89	8.73	8.73	6.75	6.71	17.07	17.64
Morpholino-	3	95	180–182.5	A	$C_8H_{16}ClNO_3$	45.82	45.92	7.69	7.70	6.68	6.82	...	...
N-Methylbenzylamino-	3	89	172.5–174.5	A	$C_{12}H_{18}ClNO_2$	59.13	59.41	7.44	7.59	5.75	6.04	14.55	15.12
Dibenzylamino-	3	90[a]	135.5–136.5	B	$C_{18}H_{22}ClNO_2$	67.59	67.36	6.93	6.74	4.38	4.49	11.09	10.97
Diethylamino-[b]	3	83	167–170	C	$C_8H_{18}ClNO_2$	49.10	49.38	9.27	9.13	7.16	7.38	...	...
Di-*n*-propylamino-	3	88	119–121	C	$C_{10}H_{22}ClNO_2$	53.68	53.65	9.91	9.64	6.26	6.14	15.85	15.72
Diisopropylamino-	3	77	141.5–144	C	$C_{10}H_{22}ClNO_2$	53.58	53.57	9.91	9.75	6.26	6.40	15.85	15.63
Dimethylamino-	4	97	163–165	C	$C_7H_{16}ClNO_2$	46.28	46.66	8.88	9.06	7.71	7.68	19.52	19.37

[a] Prepared from free acid; latter obtained by saponification of methyl ester. [b] Reported[13] m.p. 166°. [c] A = acetic acid–acetone; B = acetic acid; C = acetic acid–ether.

acid hydrolysis of the corresponding methyl esters. The γ-dialkylamino acid methyl esters were prepared by condensation of the appropriate secondary amine with methyl γ-iodobutyrate,[13] prepared in turn from γ-butyrolactone. Methyl δ-dimethylaminovalerate was prepared from 1-(N,N-dimethylamino)-3-chloropropane by a malonic ester synthesis.[14] A more general synthesis of δ-dialkylaminovaleric esters would be by condensation of a secondary amine with methyl δ-iodovalerate.[15]

The dialkylamino ketones prepared were characterized as the semicarbazone derivatives (Table IV). In addition, 5-(1-piperidino)-pentan-2-one was characterized as the methiodide.

We wish to thank Mr. James N. Pentikis for his excellent technical assistance during this investigation.

Experimental[16]

Methyl γ-Dialkylaminobutyrates.[13]—A solution of methyl γ-iodobutyrate and 4 equivalents of secondary amine in benzene was warmed at 60° for 3 hours. After cooling, the precipitate of amine hydroiodide was removed, the filtrate concentrated, and the product distilled under reduced pressure. With certain secondary amines it was necessary to carry out the reaction in toluene solution and with heating under reflux. The methyl γ-dialkylaminobutyrates prepared are listed in Table I.

γ-Dialkylaminobutyric Acid Hydrochlorides.[13]—A solution of the methyl γ-dialkylaminobutyrate in 18% aqueous hydrochloric acid was heated under reflux for 6–8 hours. The solution was taken to dryness under reduced pressure, and the solid residue crystallized from a suitable solvent. Pertinent data on the γ-dialkylaminobutyric acid hydrochlorides are given in Table II. Methyl γ-(N,N-dicyclohexylamino)-butyrate and methyl γ-(N,N-dibenzylamino)-butyrate were hydrolyzed with aqueous potassium hydroxide.

γ-Dialkylaminobutyric Acids.—An aqueous solution of the γ-dialkylaminobutyric acid hydrochloride was adjusted to *p*H 7.0 with aqueous sodium hydroxide. After removal of the water under reduced pressure, the dry residue was extracted with several portions of hot chloroform. These combined chloroform extracts were evaporated under reduced pressure, and the residue of crude γ-dialkylamino butyric acid used without purification.

δ-Dialkylaminovaleric Acid.[14]—Ethyl malonate (120 g.) was added to a solution of 15 g. of sodium in 500 ml. of absolute ethanol (redistilled from magnesium ethylate). A solution of 505 g. of 3-(N,N-dimethylamino)-propyl chloride hydrochloride in 100 ml. of absolute ethanol was

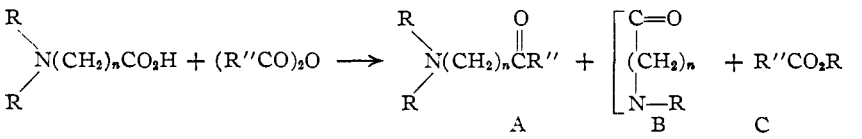
(13) F. F. Blicke, W. B. Wright and M. F. Zientz, *J. Am. Chem. Soc.*, **63**, 2488 (1941).

(14) C. S. Marvel, W. H. Zartman and O. D. Bluthardt, *ibid.*, **49**, 2299 (1927).

(15) N. J. Leonard and W. E. Goode, *ibid.*, **72**, 5404 (1950).

(16) All melting points are corrected; all boiling points are uncorrected. We are indebted to S. M. Nagy, Massachusetts Institute of Technology, Cambridge, Mass., and A. Bernhardt, Max Planck Institute, Mulheim, Germany, for the microanalyses.

TABLE III

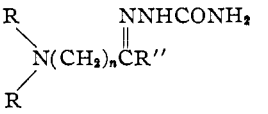


R₂N–	n	R''	Product	Yield, %	B.p. °C.	B.p. Mm.	$n^{t}D$	t, °C.	Empirical formula	Carbon, % Calcd.	Carbon, % Found	Hydrogen, % Calcd.	Hydrogen, % Found	Nitrogen, % Calcd.	Nitrogen, % Found
Piperidino-	3	CH_3	A	58	97	7	1.4628	23	$C_{10}H_{19}NO$	70.96	70.56	11.31	11.22	8.28	8.34
Morpholino-	3	CH_3	A	58	81	0.5	1.4630	24	$C_9H_{17}NO$	63.12	63.04	10.01	9.82	8.18	8.16
Morpholino-	3	C_2H_5	A	57	92	0.75	1.4627	25	$C_{10}H_{19}NO_2$	64.83	64.93	10.34	10.36	7.56	7.75
N-Methylbenzylamino-	3	CH_3	A	12	119–122	1.2	1.5009	23	$C_{13}H_{19}NO$	...	...	...	...	6.82	6.99
			B[a]	67	.....	..	1.4655	23	.....	...	...	...	...	...	...
			C[a]	57	.....	..	1.4980	23	.....	...	...	...	...	...	...
Dibenzylamino	3	CH_3	B[b]	71	125–126	−78	1.5502	23	$C_{11}H_{15}NO$	75.40	75.65	7.48	7.50	8.00	7.90
			C[b]	60	81–84	8	1.4988	23	.....	...	...	...	...	...	...
Dicyclohexylamino-	3	CH_3	B[c]	85	102	0.6	1.4985	24	$C_{16}H_{17}NO$	71.81	72.00	10.25	10.02	8.38	8.84
Diethylamino-	3	CH_3	A[d]	47	180–183	760	1.4462	24	$C_{13}H_{27}NO_5$	56.29	56.00	9.81	9.77	5.05	5.35
Dipropylamino-	3	CH_3	A[d]	64	98	9	1.4369	24	.....	...	...	...	...	...	...
Diisopropylamino-	3	CH_3	B[e]	66	82.5	7	1.4581	26	$C_7H_{13}NO$	66.10	65.70	10.30	10.19	11.02	10.76
Dimethylamino-	4	CH_3	A[d]	42	85–88	11	1.4474	22	.....	...	...	...	...	...	...

[a] B = 1-methylpyrolidone; C = benzyl acetate; compounds could not be separated by distillation. Countercurrent distribution between water and ether gave pure substances, identified by refractive index and infrared spectrum. [b] B = benzylpyrrolidone; C = benzyl acetate. [c] B = cyclohexylpyrrolidone; co-product (cyclohexylacetate) was not isolated. [d] Distilled with two moles of acetic acid; mixtures converted directly to semicarbazone derivatives. [e] B = isopropylpyrrolidone; co-product (isopropyl acetate) was not isolated.

TABLE IV

SEMICARBAZONE DERIVATIVES



R₂N–	n	R''	M.p., °C.	Crystn. solvent	Empirical formula	Carbon, % Calcd.	Carbon, % Found	Hydrogen, % Calcd.	Hydrogen, % Found	Nitrogen, % Calcd.	Nitrogen, % Found
Piperidino-	3	CH_3	132–133	Benzene–pet. eth.	$C_{11}H_{22}N_4O$	58.37	58.43	9.80	9.66	24.76	25.00
Morpholino-	3	CH_3	145–146	Tetrahydrofuran–pet. ether	$C_{10}H_{20}N_4O_2$	52.61	52.94	8.83	9.02	24.54	24.79
Morpholino-	3	C_2H_5	146–147	Methylene chloride–ether	$C_{11}H_{22}N_4O_2$	54.52	54.24	9.15	9.12	23.12	23.09
N-Methylbenzylamino-	3	CH_3	105–107	Acetone	$C_{14}H_{22}N_4O$	64.09	64.20	8.45	8.64	21.36	21.52
Diethylamino-	3	CH_3	93.5–94.5	Ether–pet. eth.	$C_{10}H_{22}N_4O$	56.04	56.07	10.35	10.09	26.14	26.00
Di-*n*-propylamino-	3	CH_3	84–85.5	Pet. ether	$C_{12}H_{16}N_4O$	59.47	59.58	10.81	10.42	23.12	22.74
Dimethylamino-	4	CH_3	95–97	Methylene chloride–pet. ether	$C_9H_{20}N_4O$	53.97	54.29	10.07	10.18	27.97	28.19

added, and the resultant mixture heated under reflux for 18 hours. After distilling out the bulk of the ethanol, the mixture was taken up in water and extracted with several portions of ether. The product was extracted from the ether with 5% aqueous hydrochloric acid, the aqueous solution made basic with aqueous sodium hydroxide, and the product again taken up in ether. After evaporation of the solvent, the diethyl α-(γ-dimethylaminopropyl)-malonate was distilled under reduced pressure (26% yield); b.p. 138–141° (10 mm.), $n^{22}D$ 1.4362.

The diethyl α-(γ-dimethylaminopropyl)-malonate was simultaneously hydrolyzed and decarboxylated by heating a solution in 18% aqueous hydrochloric acid under reflux for 8 hours. Pertinent data on δ-dimethylaminovaleric acid hydrochloride are given in Table II.

Free δ-dimethylaminovaleric acid was obtained in the manner described for the isolation of γ-dialkylaminobutyric acids.

γ-Dialkylaminovaleric Acid.—Methyl γ-chlorovalerate, prepared from γ-valerolactone with anhydrous hydrogen chloride in methanol, was converted to methyl γ-iodovalerate by means of sodium iodide in acetone; b.p. 85–88° (23 mm.), $n^{23}D$ 1.4360. Crude methyl γ-(4-morpholino)-valerate was obtained in 23% yield by heating a xylene solution of methyl γ-iodovalerate and four equivalents of morpholine under reflux for 8 hours; b.p. 145–147° (26-mm.), $n^{23}D$ 1.4555. Acid hydrolysis of the methyl ester afforded crystalline γ-(4-morpholino)-valeric acid hydrochloride, m.p. 155–158° after recrystallization from ethanol–ether.

Anal. Calcd. for $C_9H_{18}NO_3Cl$: C, 48.32; H, 8.11; N, 6.26; Cl, 15.85. Found: C, 48.43; H, 7.83; N, 6.08; Cl, 15.31.

Reaction of Dialkylamino Acids with Carboxylic Acid Anhydrides.—The dialkylamino acid was dissolved in acetic anhydride (1:4, wt.:vol.) or in a propionic anhydride–xylene mixture (1:3.2, wt.:vol.). The solution was heated under reflux for 15 minutes under an atmosphere of purified nitrogen. Effluent gases from the reaction were passed through a barium hydroxide solution; appearance of a precipitate (barium carbonate) indicated that ketone formation was taking place. Excess anhydride and solvent were then distilled at atmospheric pressure until the pot temperature reached 180–200°. The products were then recovered by distillation under reduced pressure; the substances obtained are given in Table III. The ketone formed from γ-(4-morpholino)-valeric acid was not isolated; the pot residue after distillation of excess acetic anhydride was used for semicarbazone formation.

Preparation of Derivatives. A. Semicarbazones (Table IV).—Semicarbazone derivatives of the ketonic products

were prepared in the usual manner. The derivatives were isolated by extraction of the reaction mixtures with methylene chloride (after having been made alkaline with sodium hydroxide). The semicarbazone (m.p. 93–94°) of a commercial sample of 5-diethylamino-2-pentanone[17] was identical to the semicarbazone (m.p. 93.5–94.5°) of the ketone obtained from the reaction of γ-diethylaminobutyric acid and acetic anhydride; mixture m.p. 92–94°.

The semicarbazone of 5-(4-morpholino)-hexan-2-one had a m.p. 135–137° after recrystallization from methylene chloride–petroleum ether.

Anal. Calcd. for $C_{22}H_{22}N_4O_2$: C, 54.52; H, 9.15; N, 23.13. Found: C, 54.99; H, 9.39; N, 22.50.

B. Methiodide.—A methiodide of 5-(1-piperidino)-2-pentanone was prepared by refluxing a solution of the ketone in acetone and methyl iodide for 2 hours. After recrystallization from acetone ether the derivative had m.p. 70–72°.

Anal. Calcd. for $C_{11}H_{22}NOI$: C, 42.45; H, 7.13; N, 4.50; I, 40.78. Found: C, 42.61; H, 6.93; N, 4.52; I, 40.90.

[CONTRIBUTION FROM THE DEPARTMENT OF CHEMISTRY, BRANDEIS UNIVERSITY, WALTHAM 54, MASS.]

Preparation and Kinetics of Decomposition of a Bicyclic Azo Compound. A Novel Reduction[1]

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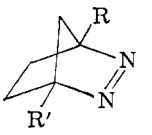
RECEIVED JANUARY 12, 1961

The decomposition of the azo compound 2,3-diazabicyclo[2,2,1]-2-heptene (I) has been studied in the gas phase from 131.5° to 180.8°. The reaction shows first-order kinetics, k_1 $7.2 \times 10^{14} e^{-37,300/RT}$, $\Delta S^{\ddagger}$ 8.7 E.U. The data are compared with those for acyclic aliphatic azo compounds. Attempts to prepare the $\Delta^{5,6}$-unsaturated analog of I from the adduct of diethyl azodicarboxylate to cyclopentadiene led to a novel reduction reaction and formation of I. Reaction of 1,4-diphenyl-1,3-cyclopentadiene with diethyl azodicarboxylate is described.

As part of our study of the effects of structure on the ease of decomposition of azo compounds, it appeared of interest to prepare and examine the kinetics of decomposition of a bicyclic azo compound of type I. We are reporting at this time

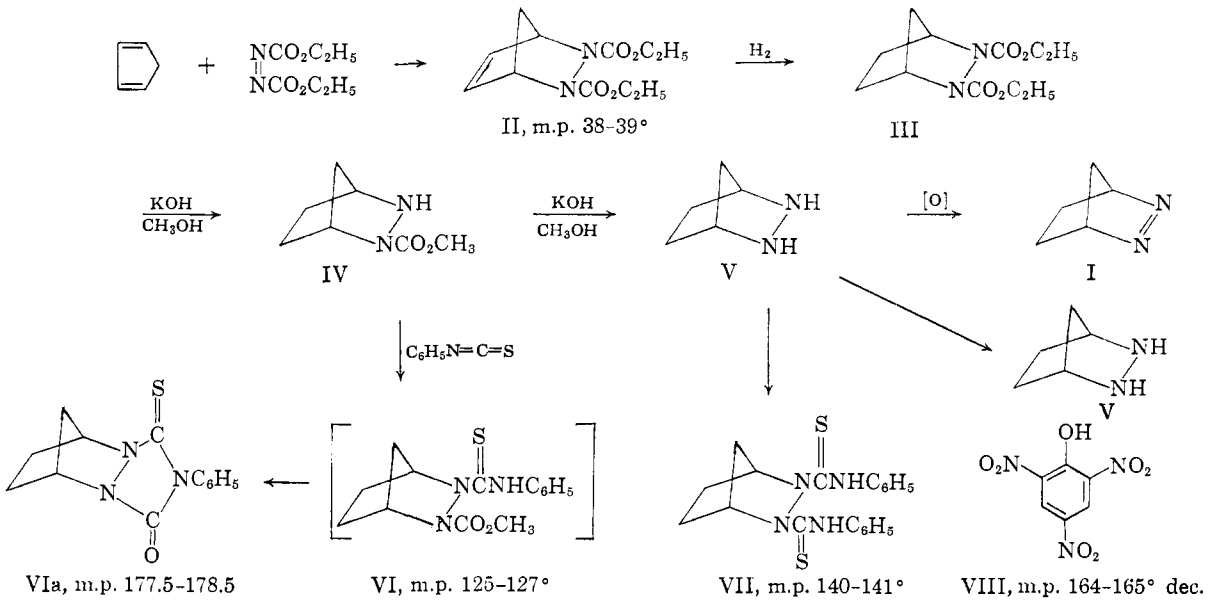


I

on some synthetic work directed toward such compounds and a related unsaturated $\Delta^{5,6}$-compound, and on the kinetics of decomposition of compound I, R = R′ = H, 2,3-diazabicyclo[2,2,1]-2-heptene.

(1) We are pleased to acknowledge generous support of this work by the National Science Foundation, Grant G.4244.

Synthetic Work.—Compound I was prepared by the sequence of reactions described in the literature[2]: addition of diethyl azodicarboxylate to cyclopentadiene, forming II, which we find to be a solid, m.p. 38–39°; catalytic hydrogenation to III; saponification to the mono-ester IV, and to the hydrazo compound V. Oxidation of hydrazo compound V to azo compound I proceeds very readily, and apparently was effected inadvertently in one of our experiments by air in the presence of cuprous chloride instead of by cupric chloride as directed,[2] the cuprous chloride complex



II, m.p. 38–39° III IV V I VIa, m.p. 177.5–178.5 VI, m.p. 125–127° VII, m.p. 140–141° VIII, m.p. 164–165° dec.

of the azo compound being formed in both cases. The oxidation also was effected readily by mercuric oxide,[3] a preferred reagent for this purpose.

(2) O. Diels, J. H. Blom and W. Koll, *Ann.*, **443**, 243 (1925).

(3) S. G. Cohen and C. H. Wang, *J. Am. Chem. Soc.*, **77**, 2457 (1955).