during Stobbe condensations.[4] However, the migration of the double bond of VId or VIId (yielding VIII after saponification) should be more favored than the case of VIa or VIIa since the proton which must be abstracted is further removed from the carboxylate anion.

A second crystalline compound [m.p. 191–192°; $C_{15}H_{16}O_6$; $\lambda_{\max}^{\text{EtOH}}$ 263 mμ (ε 19,700); $\nu_{\max}^{\text{KBr}}$ 3400–2600, 1745, 1715, and 1700 cm.$^{-1}$], also derived from a "normal" Stobbe product, was isolated from the saponification products in 17% yield (based on benzaldehyde). The nuclear magnetic resonance spectrum of this compound is summarized in Table I. On the basis of the spectral and analytical data it may be formulated as VIb, VIc, VIIb, or VIIc. However, the fact that the compound is completely unchanged after treatment with (a) boiling aqueous potassium hydroxide for 5 hr. or (b) boiling 7% sulfuric acid for 1 hr. eliminates VIc and VIIc from consideration. No attempt was made to distinguish between VIb and VIIb although VIIb seems to be the more likely since it has the more hindered ester function.

TABLE I

N.M.R. SPECTRUM[a] OF VIIb (OR VIb)

Assignment[b]	τ	Relative area	Multiplicity	J (c.p.s.)
$-CH{=}C<$	1.90	1	1	
C_6H_5-	2.65	5	1	
$-CH<$	5.27	1	4	8.2, 5.5
$-C\mathit{H}H-$	6.60	1	4	8.2, 17.2
$-CH\mathit{H}-$	7.31	1	4	5.5, 17.2
$O-C\mathit{H}_2CH_3$	5.62	2	4	7.0
$O-CH_2C\mathit{H}_3$	8.63	3	3	7.0

[a] Spectrum was measured in trifluoroacetic acid. [b] The acidic protons were indistinguishable from the protons of the solvent.

Compounds resulting from condensation at the methyne carbon of ethyl tricarballylate were not found, but the conclusion that such compounds were not formed cannot be drawn since the two compounds isolated account for only 19% of the benzaldehyde used in the condensation.

Experimental

Condensation of Benzaldehyde and Ethyl Tricarballylate.—The condensation was effected by sodium hydride in benzene according to the method described[2] using 5.79 g. (0.0547 mole) of benzaldehyde, 21.33 g. (0.082 mole) of ethyl tricarballylate, and 1.96 g. (0.082 mole) of sodium hydride. The mixture of acidic esters obtained was dissolved in 5% aqueous sodium hydroxide and heated to boiling for 30 min. The reaction mixture was cooled, acidified with dilute hydrochloric acid, and extracted with ether. The ethereal solution was dried over sodium sulfate, filtered, and evaporated *in vacuo*. A portion of the residue crystallized and was collected on a filter and washed with ether. The crystals (compound VIIb or VIb) weighed 2.54 g. and melted at 188–191°. Repeated recrystallization from methanol–water gave crystals melting at 191–192°. This compound was recovered unchanged after treatment with boiling 20% potassium hydroxide or boiling 7% sulfuric acid. The spectra are described in the above discussion.

Anal. Calcd. for $C_{15}H_{16}O_6$: C, 61.64; H, 5.52. Found: C, 61.78; H, 5.61.

The noncrystalline mixture was steam distilled until the distillate was clear (750 ml.), and the distillate was extracted with ether which was then dried over sodium sulfate, filtered, and evaporated *in vacuo*. The resulting oil (210 mg.) crystallized on cooling to −10°. The crystals were twice recrystallized from pentane yielding 140 mg. of benzylmethylmaleic anhydride III, m.p. 41–42°. Sublimation at 70° and 0.08 mm. of Hg raised the melting point to 42.5–43.0°. The spectra are described in the above discussion.

Anal. Calcd. for $C_{12}H_{10}O_3$: C, 71.26; H, 4.98. Found: C, 71.22; H, 5.16.

Benzylmethylmaleic Anhydride III (from Ethyl 2-Benzylacetoacetate).—Hydrogen cyanide was prepared[5] from 50.0 g. (1.02 mole) of sodium cyanide and collected in a flask cooled to −70°, then transferred to an ice–salt bath. Ethyl 2-benzylacetoacetate (10.0 g., 0.045 mole), prepared by the general procedure described,[6] was dissolved in 30 ml. of dry benzene, cooled to −5°, and added to the hydrogen cyanide. Triethylamine (1.0 ml.) was added and the mixture was stirred for 5 hr. at −5°. The reaction mixture was washed four times with ice-cold water, once with 4% sodium hydroxide solution, once with 2% hydrochloric acid, and finally with saturated sodium chloride solution. The benzene solution was dried over magnesium sulfate, filtered, and the benzene removed *in vacuo* to give 11.15 g. of an oil; $\nu_{\max}^{\text{CHCl}_3}$ 3460, 2250 (very weak), 1740, and 1720 cm.$^{-1}$. Thin layer chromatography indicated that the oil consisted of a 9:1 mixture of diastereomeric cyanohydrins and starting material. A portion of the oily mixture (9.91 g.) was heated to reflux with 150 ml. of concentrated hydrochloric acid for 4 hr. The cooled reaction mixture was diluted with water and extracted with ether. The ether solution was washed several times with saturated sodium bicarbonate solution, once with water, then dried over sodium sulfate, filtered, and evaporated to give 1.00 g. of an oil which has all the infrared bands of methylbenzylmaleic anhydride and a band at 1720 cm.$^{-1}$ corresponding to 4-phenylbutan-2-one. The oil was steam distilled and 600 mg. of material was reisolated from the steam distillate by extraction with ether. After four recrystallizations from pentane there was obtained 140 mg. of benzylmethylmaleic anhydride, m.p. 42.5–43.0°. The ultraviolet and infrared spectra were identical with those of the anhydride prepared by the condensation, and the melting point of a mixture of the two materials was undepressed.

Acknowledgment.—The author wishes to thank Professor E. E. van Tamelen for valuable discussions and the National Science Foundation for a predoctoral fellowship. This research was supported by the U. S. Public Health Service through Grant No. AI-5102-02.

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[4] The condensation of diethyl glutarate with benzophenone fails under the same conditions which promote condensation of diethyl succinate with benzophenone in 90% yield; see W. S. Johnson, A. L. McCloskey, and D. A. Dunnigan, *J. Am. Chem. Soc.*, **72**, 514 (1950).

(5) K. H. Slotta, *Ber.*, **67**, 1028 (1934).

(6) H. E. Zaugg, D. A. Dunnigan, R. J. Michaels, L. R. Swett, T. S. Wang, A. H. Sommers, and R. W. DeNet, *J. Org. Chem.*, **26**, 644 (1961).

The Preparation of Parabanic Acids from 1,1,3-Trisubstituted Ureas *via* a Hofmann Elimination Reaction

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Received April 2, 1964

Previously we reported[1] a novel intramolecular cyclization of propynyl ureas to 2-imidazolones *via* an isolable intermediate imidazolinium salt. Cyclization was achieved with a variety of strong acids and chlorinating agents.[1c] Since the reaction of amides with oxalyl chloride[2] has been studied in our laboratories

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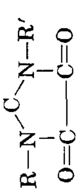
(1) (a) P. J. Stoffel and A. J. Speziale, *J. Am. Chem. Soc.*, **84**, 501 (1962); (b) P. J. Stoffel and A. J. Speziale, *J. Org. Chem.*, **27**, 3079 (1962); (c) P. J. Stoffel and A. J. Speziale, *ibid.*, **28**, 2917 (1963).

(2) A. J. Speziale and L. R. Smith, *ibid.*, **27**, 4361 (1962); **28**, 1805 (1963).

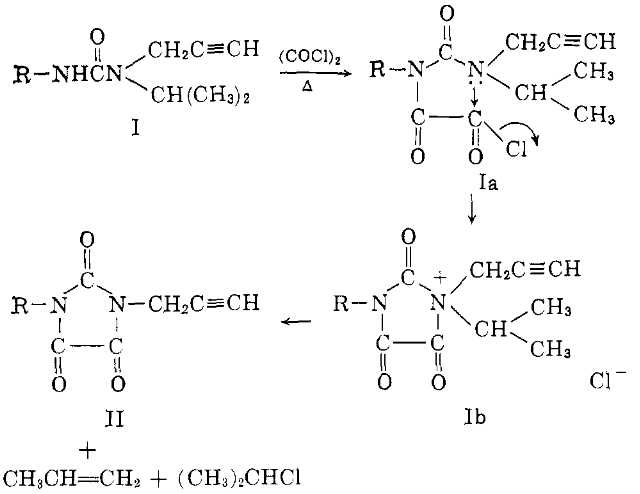
TABLE I
PARABANIC ACIDS



R	R′	Eliminated group	X	Pro-cedure	Mol. wt.	M.p., °C.	% yield	Carbon, % Calcd.	Carbon, % Found	Hydrogen, % Calcd.	Hydrogen, % Found	Nitrogen, % Calcd.	Nitrogen, % Found	Chlorine, % Calcd.	Chlorine, % Found
3,4-Dichlorophenyl	2-Propynyl	Isopropyl	O	A	297.1	188.7–189.1	81.5	48.50	48.58	2.10	1.89	9.44	9.53	23.72	23.85
3,4-Dichlorophenyl	Allyl	Isopropyl	O	A	299.1	113.4–114.0	66.6	48.25	48.20	2.67	2.67	9.37	9.26	23.63	23.71
3,4-Dichlorophenyl	H	H	O	A	259.1	233.5–234.1	65.0	41.75	42.06	1.54	1.58	10.80	10.70	27.40	27.05
3,4-Dichlorophenyl	4-Chlorophenyl	H	O	A	369.6	273–274	69.2	48.75	48.71	1.90	1.96	7.59	7.60	28.80	28.83
3,4-Dichlorophenyl	3,4-Dichlorophenyl	H	S	A	420.6	210.8–211.5	39.3	S7.63	S7.63			6.68	6.64	33.80	34.16
4-Ethoxyphenyl	2-Propynyl	Isopropyl	O	A	272.2	166.3–166.8	72.7	61.75	61.79	4.42	4.38	10.32	10.30	...	...
3,4-Dichlorophenyl	Isopropyl	Isopropyl	O	A	301.2	122.4–123.5	52.2	47.95	47.98	3.32	3.09	9.33	9.28		
4-Methylphenyl	2-Propynyl	Isopropyl	O	A	242.1	179.8–180.3	81.5	64.50	64.23	4.14	4.00	11.55	11.50		
3,4-Dichlorophenyl	Cyclohexyl	Cyclohexyl	O	A	341.4	161.7–162.5	74.0	...	...	...	...	8.20	8.20	20.80	20.74
3,4-Dichlorophenyl	Methyl	Cyclohexyl	O	A	273.1	217.2–217.9	73.7	...	...	...	...	10.25	10.06	26.00	26.01
3,4-Dichlorophenyl	*sec*-Butyl	*sec*-Butyl	O	A	315.1	100.7–101.3	88.5	...	...	...	...	8.90	9.00	22.50	22.52
H	Carbethoxymethyl	H	O	A	200.2	169.1–170.1	78.5	42.00	41.85	4.00	4.05	14.00	14.17	...	...
p-Toluenesulfonyl	Butyl	H	O	A	324.1	125.0–125.8	76.0	S9.88	S9.85			8.65	8.56		
4-Nitrotoluenesulfonyl	H	H	O	A	299.2	178.1–179.0	58.0	S10.70	S10.57			14.05	14.03	...	...
Ethyl	Ethyl	H	S	A	186.1	99.5–100.3	77.0	S17.20	S17.04			15.05	14.96		
Isopropyl	Isopropyl	H	S	A	214.1	131.0–131.7	79.9	S14.95	S15.00			13.10	13.10	...	...

and the reaction of oxalyl chloride with 1,3-disubstituted ureas to produce parabanic acids is well known,[3] we undertook the investigation of 1,1,3-trisubstituted ureas with the same reagent. This reaction has not been recorded in the literature.

In a typical case, treatment of 3-(3,4-dichlorophenyl)-1-isopropyl-1-(2-propynyl) urea (I) with oxalyl chloride in benzene at reflux gave the crystalline 3-(3,4-dichlorophenyl)-1-(2-propynyl)parabanic acid (II). Cyclization is accompanied by elimination of olefin and/or alkyl halide *via* a typical Hofmann elimination. The



I

Ia

Ib

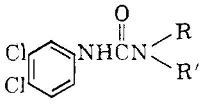
II

$CH_3CH{=}CH_2 + (CH_3)_2CHCl$

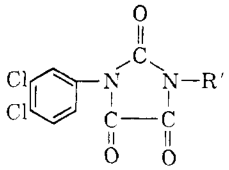
R = 3,4-dichlorophenyl

elimination reaction is general in scope as shown in Table I which includes thioureas, hydantoates, and sulfonylureas.

Qualitatively, our data show the predictably more facile leaving groups are eliminated preferentially, *i.e.*, in agreement with the ease of formation and stability of the carbonium ion involved: $(CH_3)_3C > (CH_3)_2CH > CH_3CH_2 > CH_3$. This is shown in the following chart in which treatment of the urea V with oxalyl chloride gives the R′-substituted parabanic acid VI *via* elimination of the R group.



V



VI

R	R′
isopropyl	propynyl
sec-butyl	propynyl
isopropyl	methyl
cyclohexyl	methyl
isopropyl	allyl
cyclohexyl	allyl
allyl	allyl

That the allyl group is eliminated with difficulty is reflected in the 7% yield obtained.[4] A plastic polymer was obtained presumably through an allene intermediate.

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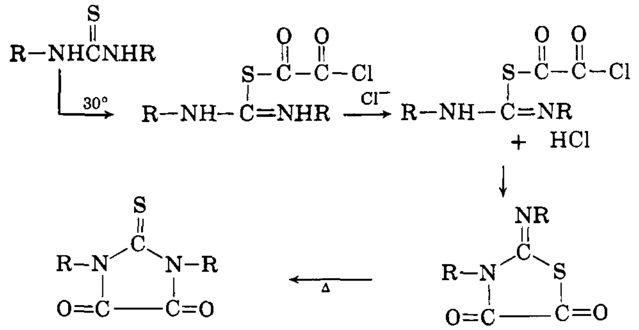
(3) T. Beltz and R. Topp, *Ber.*, **46**, 1398 (1913); J. Stojentin, *J. prakt. Chem.*, [2]**32**, 18 (1885).

(4) The allyl group is a very poor leaving group, although allyl should form a very stable carbonium ion. Other factors, therefore, must be operative in this case. We have considered the inductive effects of an allyl group in Ia, a concerted mechanism for Ia–b, or that steps Ia, Ib, and II are reversible. We do not feel that any one mechanism is preferred until more data are obtained.

The synthesis provides a convenient route to 1,3-substituted parabanic acids using readily available 1,1,3-trisubstituted ureas. The alkyl groups are readily identified by n.m.r., leaving no doubt of the identity of the leaving group. Typical spectra for substituted parabanic acids show chemical shifts, a doublet (CH) at τ 5.65 and a quartet (CH_2) at 7.30 for the 2-propynyl group. The allyl group gives a septet (CH) at τ 4.50, a multiplet ($CH_2=$) at 5.00 and a quartet (CH_2) at 5.90. The isopropyl analog shows a septet (CH) at τ 5.65 and a doublet (CH_3) at 8.60. Spectra were measured on the Varian A-60 at 60 Mc./sec. using tetramethylsilane standard.

When 1,3-diisopropyl thiourea was treated with oxalyl chloride in refluxing benzene, the expected thioparabanic acid was obtained. When treated at 30–35°, an oil possessing a strong C=N band at 6.1 μ was obtained. The spectra strongly suggests that reaction occurred *via* attack of oxalyl chloride on sulfur to form the isomeric iminothiazolidine-4,5-dione (III).



The oil gradually formed on standing, or more rapidly on heating, a yellow solid, m.p. 128°, identified as the 2-thioparabanic acid (IV). Although an intermediate comparable to III was not observed in the reaction of ureas with oxalyl chloride, it seems likely that the reaction follows a similar course.

Experimental

3-(3,4-Dichlorophenyl)-1-(2-propynyl)parabanic Acid[5] (II).— A solution of 3-(3,4-dichlorophenyl)-3-isopropyl-3-(2-propynyl)-urea (28.5 g., 0.1 mole) and oxalyl chloride (13.0 g., 0.11 mole) in 100 ml. of benzene[6] was refluxed for 8 hr.[7]; HCl was evolved freely. The product separated on cooling. Recrystallization from methanol gave small colorless granules, m.p. 188.6–189.1°.

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[5] All compounds reported in Table I were prepared using this procedure with the appropriate urea.

[6] Benzene, toluene, or xylene can be used equally well.

[7] Heating time can be reduced: reaction can be followed and quenched when the evolution of HCl ceases.

The Preparation of Oxazolidinetriones. A Novel Cyclic Anhydride Derived from Carbamates and Oxalyl Chloride

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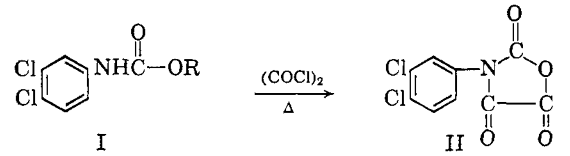
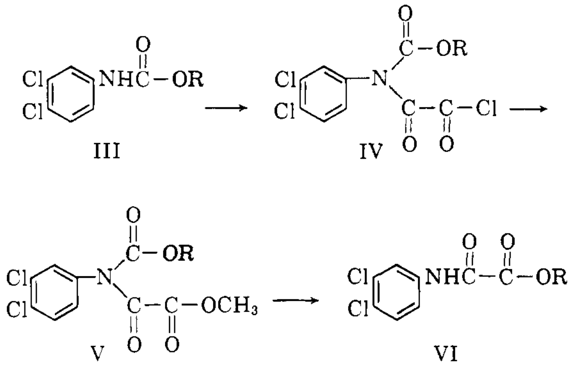
We have shown[1] that treatment of 1,1,3-trisubstituted alkyl ureas with oxalyl chloride gave parabanic acids *via* elimination of an alkyl group as olefin and/or halide. It seemed plausible that alkyl carbamates and carbanilates might react in an analogous manner under similar conditions. Isopropyl 3,4-dichlorocarbanilate (I) on refluxing in benzene with a slight excess of oxalyl chloride gave 3-(3,4-dichlorophenyl)oxazolidinetrione (II) with elimination of propylene (see Table I for physical constants). This ring system has not been reported.



a, R = i-C_3H_7; b, R = sec-C_4H_9; c, R = t-C_4H_9[2]; d, R = i-C_4H_9; e, R = C_6H_{11}

The same treatment of the *sec*-butyl, *t*-butyl, isobutyl, or cyclohexyl 3,4-dichlorocarbanilates gave II.

When the methyl, ethyl, and *n*-propyl 3,4-dichlorocarbanilates were similarly treated, the anhydride (II) was not obtained, but instead 60–80% yields of the corresponding carboalkoxy-3,4-dichlorooxanilyl chlorides (IV) were obtained. The cyclization (IV to II) could not be forced by increasing the reaction time from 3 to 36 hr., increasing the temperature from 80 to 210°, or using more polar solvents.



a, R = CH_3; b, R = C_2H_5; c, R = n-C_3H_7

Excess methanol and IV reacted exothermically giving the corresponding methyl carboalkoxyoxanilates (V). Ethanol and propanol gave the corresponding esters of V (see Table II for physical constants of the esters and chlorides). Refluxing IV with methanol, ethanol, or propanol, gave the corresponding oxanilates

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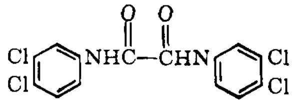
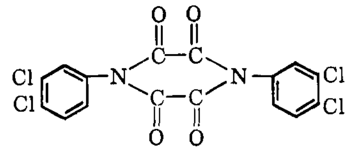
[1] P. J. Stoffel, **29**, *J. Org. Chem.*, 2794 (1964).

[2] The *t*-butyl ester, at reflux, gave two products identified as follows.



XIV

and



XV

This can be reasonably explained as a preferential acid hydrolysis of the *t*-butyl ester to the carbanilic acid with simultaneous decarboxylation to the aniline. The aniline then reacts with 1 or 2 moles of oxalyl chloride to give the two products. II was obtained by holding the reaction at 30–40°.