room temperature: yield 1.40 g (55%); IR, TLC ($CHCl_3$), and mixture melting point indicate that the material is pure **7a**. No further attempts were made to isolate **5a** from the mother liquor. If the reaction is carried out in methylene chloride as solvent, cyclization of the intermediate **11a** does not take place on refluxing.

Attempts to obtain an analytically pure sample of **11a** were unsuccessful. Reprecipitation from benzene/*n*-hexane or chloroform/hexane each gave amorphous products with a softening point around 130 °C and which gave off *N,N'*-diphenylcarbodiimide (smell). Reprecipitated samples also contain small amounts of *N,N'*-diphenylcarbodiimide (IR).

(D) From N^1,N^2,N^3-Triarylguanidines and Diphenyl Carbonate. These condensations are carried out by analogy to the ones described under B. Thus, equimolar amounts of triarylguanidine and diphenyl carbonate (in the range of 5–10 mmol each) are kept for 5–10 min in a preheated oil bath at 200–210 °C. The obtained glassy melts are taken up in 10–20 mL of methanol. (Occasionally, small amounts of *N,N'*-diarylurea remain undissolved, which are removed quickly by filtration.) The solutions deposit crystals of **7** when they are allowed to stand at room temperature. The crude products, which contain only traces of imino-*s*-triazinediones **6** (TLC with $CHCl_3$ as eluent), are recrystallized for analysis from methanol; yields are given in Table II. The filtrate gives, on careful dilution with water, a second crop of crystals, which generally consist of a mixture of **6** and **7**. In the case of **6a**, a pure sample was obtained after repeated fractional recrystallization from DMF/water which was identical with a sample prepared by a described method;[6] no attempts were made to purify samples of **6f,g**.

Reactions of Aliphatic Imides with Oxalyl Chloride

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Received March 16, 1981

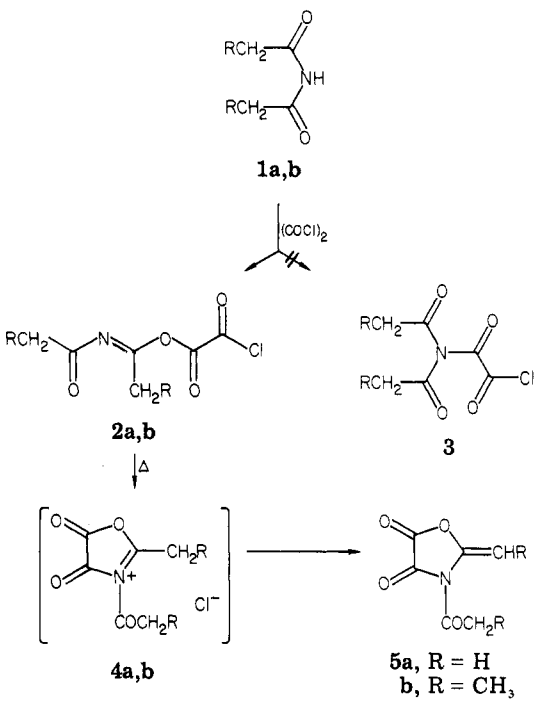
Simple aliphatic acid imides like diacetamide (**1a**), dipropionamide (**1b**), and diisobutyramide (**6**) react with oxalyl chloride with formation of O-acylated products of type **2a,b** and **7**, the structure of which was assigned on the basis of ^1H NMR and ^{13}C NMR data. Thermolysis of **2a,b** results in HCl abstraction and ring closure, giving oxazolidinediones **5a,b**. Heat treatment of **7** yields isobutyryl chloride and isobutyryl isocyanate. Glutarimide (**10a**) and adipimide (**10b**) yield fused heterocycles of type **12** directly when treated with oxalyl chloride.

Reactions of carboxylic acid amides with oxalyl chloride have been studied in detail: amides having no N-substituents were found to predominantly produce acyl isocyanates in high yields on being heated with oxalyl chloride in inert solvents.[1-5] N-Mono- and N-disubstituted amides lead to a variety of products, the nature of which depends largely upon the reaction conditions.[6,7] A thorough study about the reaction mechanism involved in the formation of O- and N-acylated products has been published by Speziale and Smith and includes a critical review of previous work on the subject.[2]

Reactions of imides with oxalyl chloride have, to our knowledge, not been studied. An investigation was undertaken to study the feasibility of preparing 2-chloro-6-oxopiperideine from glutarimide and oxalyl chloride in analogy to the related formation of imidoyl halides from amides with phosgene or thionyl chloride. The unexpected results obtained subsequently led to a study of reactions of several carboxylic acid imides with this reagent.

When diacetamide (**1a**, R = H) is heated with a slight excess of oxalyl chloride in dichloromethane solution for several hours, the starting materials are consumed, and the O-acylated product **2a** is formed in virtually quantitative yield. On following the reaction by IR, one observes that the disappearance of the carbonyl band of the imide at 1710 cm^{-1} coincides with the appearance of new bands at 1830, 1770, and 1740 cm^{-1}. The ^1H NMR spectrum of the purified product shows two signals of nearly equal intensity for the two methyl groups. This nonequivalance eliminates

Scheme I



structure **3** for the reaction product.

The O-acylated imide **2a** cyclizes on being heated in refluxing 1,2-dichloroethane to give 2-methylene-3-acetyloxazolidine-4,5-dione (**5a**). Again, the progress of the HCl abstraction can be followed by IR spectroscopy which shows the disappearance of bands characteristic of **2a** and the appearance of new bands at 1840, 1825 (double bond), 1765, 1750, and 1675 cm^{-1}. The oxazolidinedione **5a** shows two doublets for the methylene protons centered at 4.70 and 5.40 ppm each in the ^1H NMR spectrum in

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acetone-d_6. The formation can be visualized to proceed via the pathway shown in Scheme I. Dipropionamide (**1b**, R = CH_3) and oxalyl chloride react similarly when heated in 1,2-dichloroethane, giving an O-acetylated intermediate **2b**. This compound has not been isolated and characterized, but its presence was shown by the characteristic IR bands at 1830, 1775, 1755, and 1745 cm^{-1}. When the reaction solution was heated further, cyclization to **5b** (R = CH_3) takes place and is nearly complete within 3 h. The ^1H NMR spectrum of the chlorine-free product shows a quartet centered at δ 6.15 for the methine proton as a result of coupling with the geminal methyl group, which appears as a doublet centered at 1.85 ppm. The ^{13}C NMR spectrum shows only signals for one of the two possible isomers about the double bond, indicating that the cyclization is stereoselective.

The ^{13}C NMR spectra of the acyclic acyl chloride **2a** and of the oxazolidinedione derivative **5a** are also fully in agreement with the proposed structures (see Experimental Section).

The reaction of diisobutyramide (**6**) with oxalyl chloride in refluxing 1,2-dichloroethane gives quantitatively the O-acylated product **7**. The structure **7** was assigned to the product on the basis of both infrared bands similar to those observed for **2a** and **2b** and NMR data. The ^1H NMR spectrum shows two methine protons (δ 3.35, 3.70), one six-proton methyl doublet (δ 1.30), and two three-proton methyl doublets (δ 0.85 and 1.35). The magnetic nonequivalence of the four methyl groups was observed at temperatures up to 110 °C, the temperature at which the compound decomposed. This low degree of symmetry may be due to either a high barrier to rotation for one of the groups in the molecule or to isomerism about the N=C bond. Whatever the causes of the nonequivalence observed, the NMR data support structure **7** and not a symmetrical structure related to **3**.

The crowding caused by the isopropyl groups has an effect on the cyclization of the isobutyrimidate **7**. Heating of **7** without solvent to 145–150 °C leads to complete decomposition within a few hours. Isobutyryl chloride and isobutyryl isocyanate as well as minute amounts of 2-isopropylideneoxazolidine-4,5-dione (**9**) can be identified as products. Isobutyryl isocyanate and **9** were synthesized independently from isobutyramide and oxalyl chloride.

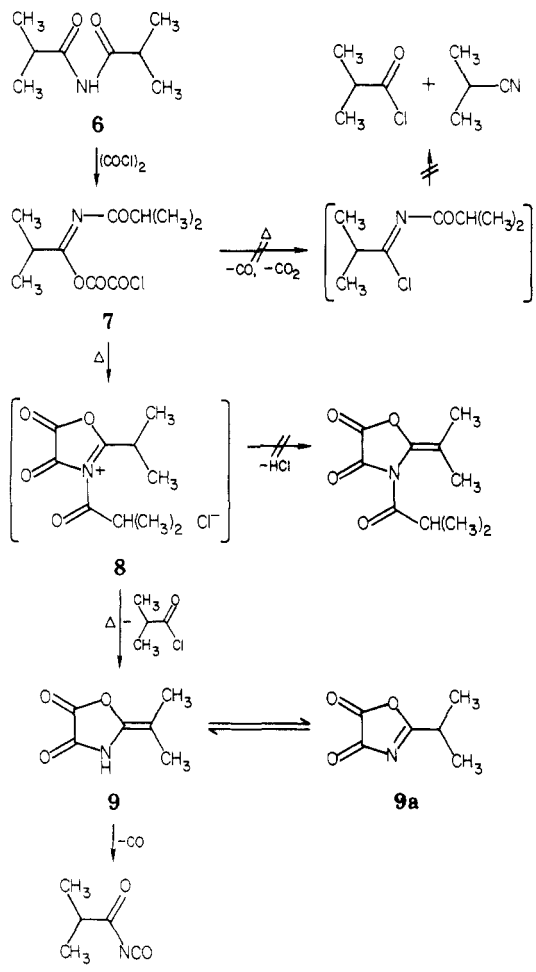
2-Isopropylideneoxazolidine-4,5-dione (**9**) shows one ^1H NMR signal for the methyl protons and a very broad NH proton, indicating that it exists preferentially in the ketene O,N-acetal form and not as isobutyrimidate **9a**. Heating of this compound in toluene leads cleanly to isobutyryl isocyanate and carbon monoxide.

The difference in the course of the thermolysis of **7** as compared with that of **2a,b** is likely to be caused by steric crowding in the cyclized intermediate **8**, which results in deacylation (giving **9**) instead of HCl abstraction.

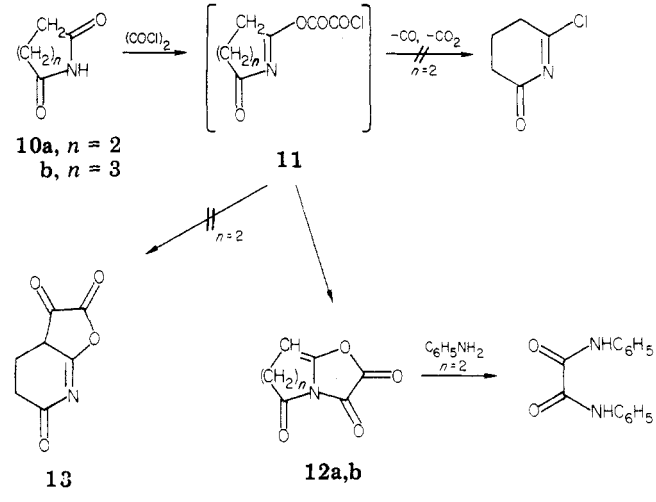
The involvement of a cyclic intermediate **8** in the decomposition becomes even more likely since no isobutyronitrile is found among the reaction products. This nitrile would arise from direct decarboxylation and decarbonylation of the acyclic imidate **7** via an unstable isobutyronitrile–isobutyryl chloride adduct (see Scheme II).

The effect of oxalyl chloride upon aliphatic cyclic imides has also been studied. As was mentioned above, the reaction of glutarimide (**10a**) with oxalyl chloride in refluxing 1,2-dichloroethane did not give 2-chloro-6-oxo-3,4-dihydro-5*H*-pyridine but produced 2,3,5-trioxo-2,3,4,5,6,7-hexahydrooxazolo[3,2-*a*]pyridine (**12a**) instead. It can be assumed that the cyclization proceeds via steps similar to

Scheme II



Scheme III



the ones described for the formation of **5a** and **6**: initial attack at one carbonyl oxygen gives an intermediate **11**, and subsequent N-acylation and HCl abstraction lead to **12a**. The formation of an isomeric furano[2,3-*b*]pyridine (**13**) as a result of ring closure at the heteroallyl carbon seems less likely. The chemical degradation of the reaction product with aniline produced oxanilide in high yield, which can easily arise from **12** (see Scheme II).

Adipimide (**10b**), the next higher homologue, reacts similarly with oxalyl chloride, giving an oxazolo[3,2-*a*]-azepine **12b**. Both **12a** and **12b** show three IR bands each in the double bond region between 1700 and 1840 cm^{-1} (see

Table I. Products from Reactions of Aliphatic Imides with Oxalyl Chloride[a]

imide	product	mp, °C	yield, %	IR (C=O), cm^{-1}
1a	**2a**	74–75	quant	1830, 1770, 1740
	5a	111–112	41[b]	1840, 1825, 1765, 1750, 1675
1b	**5b**	117–118	56[b]	1830, 1820, 1765, 1750, 1700
6	**7**	70–72	quant	1830, 1765, 1735
	9	177	<5	1815, 1735
10a	**12a**	145	57[b]	1840, 1800, 1720
10b	**12b**	147–154	60[b]	1830, 1800, 1710

[a] Satisfactory analytical values (±0.22 for C, H, N, and Cl) were reported for all compounds. [b] Yields of purified products; the actual yield was higher.

Table I). The vinylic protons of the ketene O,N-acetal group appear as triplets in each case.

When the five-membered-ring succinimide was heated with oxalyl chloride, no fused heterocycle of type **12** was formed. The oxalyl chloride was completely decomposed within 2–3 h in refluxing 1,2-dichloroethane, leaving most of the imide unchanged although the reaction solutions turned dark brown.

Experimental Section[8]

Dipropionamide and diisobutyramide were prepared according and in analogy to a literature procedure.[9]

Diacetamide and Oxalyl Chloride. (A) *O*-Chlorooxalyl *N*-Acetylacetimidate (2a). A mixture of 10.1 g (0.1 mol) of diacetamide and 13.5 g (0.106 mol) of oxalyl chloride in 40 mL of methylene chloride is heated to reflux for 3–4 h with exclusion of moisture. The progress of the reaction is monitored by following the disappearance of the C=O band of **1a** at 1710 cm^{-1} and appearance of bands at 1830, 1770, and 1740 cm^{-1} in the infrared. Evaporation of the solvent leaves a pale brown crystalline residue which can be purified by recrystallization from chloroform/*n*-hexane: colorless crystals; melting point and IR data are given in Table I; ^1H NMR ($CDCl_3$) δ 2.42 (s, CH_3), 2.62 (s, CH_3).

The ^{13}C NMR spectrum of **2a** ($CDCl_3$) shows a signal for the imino carbon at δ 105.11 while the other three carbonyl carbons appear at 150.48, 153.78, and 167.19 ppm and the methyl carbons at 25.66 and 30.50 ppm.

(B) 2-Methylene-3-acetyloxazoline-4,5-dione (5a). A mixture of the same amounts of starting materials as given in part A is heated in 40 mL of 1,2-dichloroethane at a bath temperature of 120 °C. During the reaction, copious amounts of HCl are given off, and the progress of the cyclization is followed by IR (an additional band appears at 1680 cm^{-1}). After about 4–6 h the dark brown hot reaction solution is diluted with *n*-hexane (to initiate crystallization) and kept at room temperature for several hours. The nearly colorless crystals are collected by filtration (6.34 g; mp (crude) 110–111 °C) and further purified by recrystallization from chloroform/*n*-hexane: melting point and IR data are given in Table I; ^1H NMR (acetone-*d*) δ 2.61 (s, CH_3), 4.70 (d, CH, J = 4 Hz), 5.40 (d, CH, J = 4 Hz).

The ^{13}C NMR spectrum shows only one methyl carbon at 26.10 ppm and a signal for the methylene carbon at 83.62 ppm. The three carbonyl carbons remain almost unchanged (as compared with those of **2a**) at 150.50, 152.94, and 167.83 ppm while the ketene O,N-acetal carbon appears at 142.21 ppm.

2-Ethylidene-3-propionyloxazolidine-4,5-dione (5b). A mixture of 11.30 g (0.1 mol) of dipropionamide and 13.5 g (0.106 mol) of oxalyl chloride in 40 mL of chloroform is heated to reflux for 2–3 h. During this time the starting materials are consumed, and **2b** is formed as indicated by the IR (bands at 1830, 1775, 1755, and 1745 cm^{-1}) and ^1H NMR spectra. The crude, yellow oil, which is left after solvent evaporation, is taken up in 20 mL of 1,2-dichloroethane and heated to reflux for ~3 h, during which cyclization to **5b** takes place. When the reaction solution is cooled in ice, nearly colorless crystals of **5b** are separated which are collected by filtration: 10.20 g (56%); mp 117–118 °C. A sample was recrystallized for analysis from chloroform/*n*-hexane to give off-white plates: melting point and IR data are given in Table I; ^1H NMR ($CDCl_3$) δ 1.25 (t, CH_3, J = 7 Hz), 1.85 (d, CH_3, J = 7 Hz), 3.10 (g, CH_2, J = 7 Hz), 6.15 (q, CH, J = 7 Hz); ^{13}C NMR ($CHCl_3$) δ 7.77 (CH_3), 9.69 (CH_3), 32.18 (CH_2), 95.29 (>C=), 137.06 (N–C–O), 150.73, 172.37 (C=O).

***O*-Chlorooxalyl *N*-isobutyrylisobutyrimidate (7)** is obtained in virtually quantitative yield on heating a mixture of 15.7 g (0.1 mol) of diisobutyramide and 14.0 g (0.11 mol) of oxalyl chloride in 50 mL of 1,2-dichloroethane (bath temperature 120 °C) for ~3.5–4 h. Removal of solvent leaves a nearly colorless oil which solidifies on cooling to room temperature. A sample is recrystallized for analysis from *n*-hexane, giving colorless needles of **7**. The ^{13}C NMR spectrum shows four peaks assigned to three carbonyl carbons and the one imino carbon (δ 174.6, 154.1, 150.2, and 111.2), two methine carbon peaks at δ 38.8 and 35.3, and four methyl peaks at δ 18.3, 17.8, 16.4, and 15.0; melting point and IR data are given in Table I.

Thermal Decomposition of 7. A sample of 10.0 g (0.04 mol) of **7** is kept at 145–150 °C for 2.5–3 h. The reaction flask is equipped with a reflux condenser and drying tube to avoid loss of liquid products and decomposition by moisture. During the reaction a gas is given off, and the residue turns into a mobile liquid. Progress of the reaction is indicated by appearance of new bands in the IR spectrum at 2240, 1800, 1765, and 1720 cm^{-1} while those of the starting material disappear or recede. After the reaction mixture is cooled to 50 °C, the liquid products are quickly distilled off under aspirator vacuum and collected in an ice-cooled receiver.

The distillate consists of a mixture of isobutyryl chloride and isobutyryl isocyanate. The IR spectrum (in $CHCl_3$) of this mixture is identical with that of a mixture prepared from each of the components.

The distillation residue (less than 0.5 g) is taken up in a small amount of *n*-hexane which leads to deposition of colorless crystals. Filtration yields 0.10 g (~1.5%) of 2-isopropylidene oxazolidine-4,5-dione (**9**); purification for analysis by recrystallization from chloroform/*n*-hexane, colorless needles; melting point and IR data are given in Table I.

2-Isopropylideneoxazolidine-4,5-dione (9) is obtained in 86% yield on reacting 8.70 g (0.1 mol) of isobutyramide with 13.5 g (0.106 mol) of oxalyl chloride in 40 mL of methylene chloride at room temperature for 15 h: ^1H NMR (acetone-d_6) δ 1.80 (s, CH_3), 11.20 (s, NH).

General Procedure for the Preparation of 2,3,6,7-Tetrahydro-5*H*-2,3,5-trioxooxazolo[3,2-*a*]pyridine (12a) and 2,3,5,6,7,8-Hexahydro-2,3,5-trioxooxazolo[3,2-*a*]azepine (12b). Suspensions of 0.1 mol of glutarimide (**10a**) or adipimide (**10b**) in 30–40 mL of 1,2-dichloroethane are treated with 0.11 mol of oxalyl chloride and heated to reflux for 3–4 h. The progress of the reactions is monitored by IR spectroscopy. The homogeneous, dark reaction solutions are concentrated in vacuo, and the tan, solid residues are taken up in chloroform/*n*-hexane and filtered. Samples of the heterocycles are recrystallized from chloroform or acetonitrile/chloroform (**12a**) for analysis; melting points and IR data are given in Table I. ^1H NMR (Me_2SO-d_6) of **12a**: δ 2.2–3.0 (m, 4 H), 5.1 (t, 1 H, J = 4 Hz). For **12b**: δ 1.60–2.9 (m, 6 H), 5.2 (t, 1 H, J = 4.0 Hz).

On treatment of a solution of 0.33 g (2 mmol) of **12a** in 10 mL of acetone with 0.360 g (4 mmol) of aniline a precipitate of oxanilide is formed within minutes. The solid is filtered off after 10 min: 0.35 g (73%); mp 252–253 °C; identical in mixture melting point and IR comparison with authentic material.

(8) Melting points were taken with the Fisher-Johns melting point apparatus; elemental analyses were by Galbraith Laboratories; IR spectra were determined by using a Beckman Acculab 4; ^1H NMR spectra were recorded on a Varian T60 and ^{13}C NMR spectra on a Varian CFT 20.

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