## Reaction of Trimethylsilyl Azide with Anhydrides and Imides. A New Uracil Synthesis *via* Nitrogen Insertion

STEPHEN S. WASHBURNE,\* W. R. PETERSON, JR., AND DENNIS A. BERMAN

Department of Chemistry, Temple University, Philadelphia, Pennsylvania 19122

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Trimethylsilyl azide reacts with maleic anhydride to give 1-trimethylsilyl-1,3-oxazine-2,4(6H)-dione (1) formed by cyclization of trimethylsilyl 2-isocyanatoacrylate which arises from a Curtius rearrangement of a maleic anhydride-silyl azide adduct. The analogous reaction with N-alkylmaleimides gives the cycloaddition product, 1-trimethylsilyl-4,5-dicarboximido-1,2,3-triazoline (18), which forms 2-aminomaleimides upon thermolysis. Application of the maleic anhydride reaction to N-butylisomaleimide (20) gave 3-butyluracil and a new entry into the pyrimidinedione ring system.

Organic azides are well known to behave as 1,3 dipoles toward a wide variety of olefinic<sup>1</sup> and polar unsaturated<sup>2</sup> linkages. Organometallic azides of tin<sup>3</sup> and silicon<sup>4</sup> appear to behave similarly. The reactions of maleic anhydride and N-phenylmaleimide with aryl azides are well documented, exhibiting Hammett  $\rho$ constants of -1.1 and -0.8, respectively. The rate constants for reaction with phenyl azide at 25° are respectively 72 and 2.8  $\times 10^{-6.1a}$  The reaction of trimethylsilyl azide with benzonitrile proceeded analogously to the reaction of phenyl azide with the latter substrate, affording after hydrolysis 5-phenyltetrazole and 3,5-diphenyltriazole.<sup>4c</sup> Typical conditions involve an extended reflux period in an excess of substrate.

Reactions of Trimethylsilyl Azide with Anhydrides.— The reaction of trimethylsilyl azide (TMSA) with maleic anhydride did not fit into this pattern. Admixture of the reactants gave rise to a vigorous evolution of nitrogen and a violent exotherm. With benzene as diluent the reaction was moderated, but at 50° rapid evolution of nitrogen was observed. When the reaction mixture was chilled colorless crystals,  $C_7H_{11}$ -NO<sub>3</sub>Si, were isolated whose spectral parameters were in accord with structure 1 or 2. The presence of two



resonances in the olefinic region of the nmr spectrum definitely ruled out aziridine **3**, which might have been expected to be formed by thermolysis of an initially formed  $\Delta^{2}$ -1,2,3-triazoline, e.g., **5**.<sup>5</sup>

Since the ir spectrum of the crystals showed a medium band at 990 (SiN) and only weak absorbance at 1090 cm<sup>-1</sup> (SiO), structure 1 is favored. Further work-up of the reaction mixture or, alternatively, exposure of 1 to moisture, gave 1,3-oxazine-2,4(6H)-dione (4), the *N*-carboxyanhydride of 2-aminoacrylic acid.

(1) (a) R. Huisgen, G. Szeimies, and L. Moebius, *Chem. Ber.*, **100**, 2494 (1967); (b) S. Patai, Ed., "The Chemistry of Alkenes," Interscience, New York, N. Y., 1964, pp 808-878.

(2) R. Huisgen, Angew. Chem., Int. Ed. Engl., 2, 565, 633 (1963).

(3) P. Dunn and D. Oldfield, Aust. J. Chem., 21, 645 (1971).

(4) (a) L. Birkofer and P. Wegner, Chem. Ber., 99, 2512 (1966); (b) L. Birkofer, F. Muller, and W. Kaiser, Tetrahedron Lett., 2781 (1967); (c) S. S. Washburne and W. R. Peterson, J. Organometal. Chem., 21, 427 (1970).

(5) G. Szeimies and R. Huisgen, Chem. Ber., 99, 491 (1966).

Thus the overall reaction involves the insertion of an -NH- moiety between the carbonyl and olefinic carbon atoms of maleic anhydride. At least four mechanisms (a-d) may be postulated for this transformation.



Path c and its radical analog d involve intermediates similar to those proposed by Huisgen<sup>5</sup> to obtain in the thermolysis of triazoline. By analogy to known pathways of triazoline decomposition,<sup>5</sup> 7 or 8 would be expected to cyclize to aziridine 3 or to enamine 9 via hydrogen migration. Such migration should be favored over acyl migration leading to 1. Yellow products similar to 9 were isolated from the reaction of maleimides with TMSA, vide infra, and, since the present reaction mixture took on a deep orange coloration, the presence of 9 as a minor product is a distinct possibility.

Path b bears some analogy to a Schmidt reaction, such as the conversion of substituted benzoquinones to azepinones by treatment with sulfuric and hydrazoic acids,<sup>6</sup> but collapse of 11 to product via b, which requires alkenyl group migration, must be viewed as less favorable than conversion to 10 through C-O bond rupture. Path a then proceeds through Curtius rearrangement of acyl azide 10 to isocyanate 6 which should be facile in refluxing benzene. The cyclization of 6 to 1 finds analogy in the known equilibrium between silylated N-carboxyanhydrides and the open-chain

(6) D. Misiti, H. W. Moore, and K. Folkers, Tetrahedron Lett., 1071 (1965).

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isocyanates.<sup>7</sup> That such an equilibrium exists was shown by production of the same mixture by either silylation of N-carboxyanhydrides or thermolysis of N-(phenoxycarbonyl)-N-(trimethylsilyl)amino carbox-



ylates. That such an equilibrium between 1 and 6 exists is shown by the fact that a solution ir (but not a solid phase ir) of 1 shows an absorption at 2240 cm<sup>-1</sup>.

In confirmation of the path a mechanism, we investigated the reaction of TMSA with other anhydrides. Phthalic anhydride, which could not react by path c or d, gave in 84% yield a clear liquid, 12, which solidified on standing. The nmr spectrum of 12 showed two singlets (ratio of 1:4) in the region of Me<sub>3</sub>Si resonances; the ir had both anhydride (1860, 1790 cm<sup>-1</sup>) and isocyanate (2280 cm<sup>-1</sup>) absorption. Treatment of 12 with aqueous ethanol afforded isatoic anhydride 13



in 91% yield. Cyclohexane-cis-1,2-dicarboxylic anhydride gave a product with a similar ir spectrum, but the nmr showed a single Me<sub>3</sub>Si resonance, a 1-proton signal at  $\delta$  2.41, an 0.8-proton signal at 4.20 indicative of a hydrogen adjacent to the strongly deshielding N= C=O group, and a 0.2-proton signal at 3.13 (HCNSi), implying the product to be a 1:4 mixture of N-trimethylsilyl N-carboxyanhydride and isocyanate. The  $\delta$  2.41 proton (HCCO<sub>2</sub>Si) exhibited coupling constants of 11 and 4 Hz to the adjacent methylene group, implying that the CO<sub>2</sub>Si group is equatorial. Succinic



anhydride gave, in 72% yield, trimethyl  $\beta$ -isocyanatopropionate. The ir showed no anhydride absorption and the nmr showed only two clean triplets and a Me<sub>3</sub>Si singlet. This product was previously reported to exist exclusively in the isocyanate tautomer.<sup>7</sup>

$$0 \xrightarrow{0} 0 \xrightarrow{\text{TMSA}} 0 = C = \text{NCH}_2\text{CH}_2\text{CO}_2\text{SiMe}_3$$

Table I summarizes the equilibrium positions for cyclic anhydrides. Nmr evidence points to the

TABLE I Position of the N-Carboxyanhydride-Isocyanate Equilibrium

	~% pr	oduct
	N-Carboxy-	
Anhydride	anhydride	Isocyanate
Succinic	0	100
Hexahydrophthalic	20	80
Phthalic	20	80
Maleic	100	0

phthalic and hexahydrophthalic anhydride products existing predominately in the isocyanate form. Only in the maleic anhydride case, where the cyclized form (N-carboxyanhydride) is apparently crystalline and the open-chain (isocyanate) form is liquid, does the equilibrium favor an N-carboxyanhydride.

As final confirmation, the reaction of butyric anhydride with TMSA afforded in good yield trimethylsilyl butyrate and propyl isocyanate. Thus the pos-

sibility of using trimethylsilyl azide for the conversion of anhydrides to amines with one less carbon atom is opened up.

The mechanism involving an intermediate acyl azide, path a, is favored over path b. The reaction of TMSA with aldehydes and ketones, which must proceed by a mechanism analogous to path b, requires ZnCl<sub>2</sub> catalysis.<sup>4b</sup> As the present reactions proceed in

$$\begin{array}{c} O \\ \parallel \\ \text{RCH} + Me_3 \text{SiN}_3 \end{array} \xrightarrow{\text{ZnCl}_2} & \begin{array}{c} O \\ RC \\ + \end{array} \xrightarrow{N} & \begin{array}{c} N_2^+ \\ \text{SiMe}_3 \end{array} \xrightarrow{\text{H}_2 O} & \begin{array}{c} O \\ NH_2 \end{array} \end{array}$$

the absence of Lewis acids, the direct rearrangement *via* path b is considered unlikely.

**Reactions with Maleimides.**—The facile reaction of TMSA with maleic anhydride held out the hope that a reaction with an N-substituted maleimide would afford an entry into the genetically important pyrimidinedione ring system. These hopes could not be realized. A



reaction between N-methylmaleimide and TMSA in refluxing benzene over a 2-day period evolved no nitrogen but produced an intractable red tar. Switching to the higher boiling mesitylene solvent produced N<sub>2</sub> evolution and a yellow product (15, C<sub>8</sub>H<sub>14</sub>N<sub>2</sub>O<sub>2</sub>Si), which, from an nmr spectrum that showed a single unsplit olefinic proton, was clearly not 1-trimethylsilyl-3-methyluracil (14). Hydrolysis of 15 gave 16, which was identified as N-methyl-2-aminomaleimide on the basis of the mnr spectrum, which showed a broad 2proton signal (NH), and an unsplit olefinic proton. When the reaction of TMSA with N-methylmaleimide was carried out without solvent, 16 was isolated in lower yield.

<sup>(7)</sup> G. Greber and H. R. Kricheldorf, Angew. Chem., Int. Ed. Engl., 7, 942 (1968).

A similar reaction with N-phenylmaleimide in nonane (bp  $145^{\circ}$ ) gave, after chromatography on alumina, a modest yield of N-phenyl-2-aminomaleimide (17).

We suspected that the aminomaleimide products arose via thermal decomposition of triazoline 18. Confirmation of this was found when TMSA and N-phenylmaleimide were allowed to react for 16 hr in refluxing xylene and produced 18 (R = Ph; R' = H) after work-up with aqueous ethanol. Thermolysis ( $Ph_2O$ , 200°) and chromatography afforded 17 in 68% yield.



The reaction of trimethylsilyl azide with maleimides thus offers a convenient synthesis of aminomaleimides, previously available only via treatment of bromomaleimides with sodamide<sup>8</sup> or by ammonolysis of methoxymaleic acid.<sup>9</sup> The thermolysis of **18** ( $\mathbf{R} = \mathbf{H}$ ;  $\mathbf{R}' = \mathbf{Me}_{3}\mathbf{Si}$ ) leads to enamine structures and not to aziridines **19** which are found when **18** ( $\mathbf{R} = \mathbf{Ph}$ ;  $\mathbf{R}' =$  $\mathbf{Ar}$ ) is thermolyzed.<sup>10</sup> There is no reason to believe that **19** ( $\mathbf{R}' = \mathbf{Me}_{3}\mathbf{Si}$ ) would be unstable had it been formed, for silylaziridines are well known,<sup>11</sup> and the reasons for nonformation of aziridines must lie in subtle facets of the radical character of triazoline decompositions.<sup>5</sup>

The rationale for the different courses taken by trimethylsilyl azide in its reactions with maleic anhydride and maleimides lies in two competing reactions: cycloaddition and acyl-heteroatom cleavage. With maleic anhydride, though cycloaddition to **5** is probably faster than cycloaddition of *N*-phenylmaleimide to **18**.<sup>1a</sup> cycloaddition to **5** can not compete with fast attack of azide to give **10** via acyl-oxygen cleavage. Acyl azides can be conveniently prepared from anhydrides,<sup>12</sup> but reactions of azides with imides are unknown; thus maleimides cycloadd silvl azide instead.

Synthesis of a Uracil.—We thought that, if we could couple the fast acyl-oxygen cleavage of maleic

(8) N. D. Heindel, V. B. Fish, and T. F. Lemke, J. Org. Chem., 33, 3997 (1968).

(12) J. March, "Advanced Organic Chemistry," McGraw-Hill, New York, N. Y., 1968, p 341. anhydride with a group (Z) that could reclose the sixmembered ring through attack on the isocyanate group, other heterocycles might be accessible via this trimethylsilyl azide reaction. The biologically most important of these is the pyrimidinedione ring system of uracil (Z = NR), and the synthesis of 3-butyluracil was realized when *n*-butylisomaleimide (20), readily accessible in two steps from maleic anhydride and butylamine,<sup>13</sup> was allowed to react with TMSA in mesitylene at 110° for 16 hr. The silyl group was cleaved from 21 by treatment with dry HCl in ether, affording 3-butyluracil (22).



This method of uracil synthesis should be applicable to practically any 3-substituted derivative. In addition 21 should be a valuable intermediate for the synthesis of nucleotides and nucleosides, since the synthesis of 1-glucosyluracil has been accomplished by treatment of a glucosyl bromide with bis(trimethylsilyl)uracil.<sup>14</sup> The closure of the amido isocyanate to 21 rather than to an isouracil (exocyclic ==NR) is probably merely a consequence of the preferred N-alkylation of amides under these conditions, but the detailed mechanistic steps in the conversion of 20 to 22 remain obscure at this time. Further studies on the mechanism of this synthesis of uracil derivatives are under investigation in these laboratories.

### **Experimental Section**

General Comments.—All reactions with trimethylsilyl azide were carried out under purified nitrogen in an efficient hood. Ir spectra were determined on Perkin-Elmer Models 21, 137, 225, and 700 spectrophotometers, uv spectra on a Cary Model 14 spectrophotometer, nmr spectra as 15% solutions in CDCl<sub>3</sub> containing 2% TMS on Varian Model T-60, A-60, and XL-100-15 spectrometers. Chemical shifts are given in  $\delta$  units (parts per million) downfield from internal TMS. Microanalyses were performed by Galbraith Laboratories, Knoxville, Tenn.

Trimethylsilyl azide was prepared as described by us previously.<sup>15</sup>

Reaction of Trimethylsilyl Azide with Maleic Anhydride.— Addition of 5.8 g (50 mmol) of trimethylsilyl azide to a solution of 50 mmol of maleic anhydride in 20 ml of  $C_6H_6$  and warming the mixture 16 hr at 50° caused evolution of slightly more than 1 l. of N<sub>2</sub>. Chilling the red solution to 5° caused separation of 1.4 g (15%) of 1, mp 120-122° dec, identified by spectra as N-trimethylsilyl-1,3-oxazine-2,4(6H)-dione: ir (mull) 1770, 1730, 1630, 1255, 990, 845 cm<sup>-1</sup>; nmr  $\delta$  0.48 (9 H, s, Me<sub>3</sub>Si-), 5.68 (1 H, d, J = 8 Hz, HC=CN), 7.38 [1 H, d, J = 8 Hz, >C=C-(H)N] ppm.

<sup>(9)</sup> A. Arai, M. Kado, I. Chiyomaru, Yuki Gosei Kagaku Kyokai Shi, 23, 435 (1965); Chem. Abstr., 63, 6855 (1965). A. Arai and I. Ichikizaki, Kobayashi Rigaku Kenkyushu Hokuku, 13, 52 (1963); Chem. Abstr., 63, 14382c (1965).

<sup>(10)</sup> A. Mustafa, S. M. A. D. Zayed, and S. Khattab, J. Amer. Chem. Soc., 78, 145 (1956); W. I. Awad, S. M. A. R. Omran, and F. Nageib, Tetrahedron, 19, 1591 (1963).

<sup>(11)</sup> E. Ettenhuber and K. Rühlmann, Chem. Ber., 101, 3579 (1968); N. S. Nametkin, V. N. Perchenko, M. E. Kuzovkina, and J. A. Grushebeneko, Dokl. Akad. Nauk SSSR, 182, 842 (1968).

<sup>(13)</sup> T. M. Pyriadi and H. J. Harwood, J. Org. Chem., 36, 821 (1971).

<sup>(14)</sup> T. Nishimura and I. Iwai, Chem. Pharm. Bull. (Tokyo), 12, 357 (1964); Chem. Abstr., 60, 15968b (1964).

<sup>(15)</sup> S. S. Washburne and W. R. Peterson, Jr., J. Organometal. Chem., **33**, 153 (1971).

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Anal. Calcd for C7H11NO3Si: C, 45.38; H, 5.99. Found: C, 45.83; H, 5.99.

Evaporation of the above filtrate caused separation of a redbrown taffy which was taken up in dry Et<sub>2</sub>O. Addition of *n*-hexane caused precipitation of 2.9 g (52%) of 1,3-oxazine-2,4-(6H)-dione (4): mp 158-159° dec; ir (mull) 1780, 1700, 1208, 1112, 981, 770 cm<sup>-1</sup>; nmr (DMSO-d<sub>6</sub>) δ 5.59 and 7.75 (doublets, J = 7.5 Hz, olefinic H), 8.0-12.0 (1 H, broad, seen only in inte-

gration, >NH) ppm. Anal. Calcd for C4H<sub>3</sub>NO<sub>3</sub>: C, 42.49; H, 2.67; N, 12.39. Found: C, 42.70; H, 2.88; N, 12.10.

Reaction of TMSA with Phthalic Anhydride.--A mixture of 50 mmol each of phthalic anhydride and TMSA in 50 ml of  $C_6H_6$ , heated at reflux for 3 hr, evolved 1 l. of  $N_2$ . After removal by distillation of 40 ml of C<sub>6</sub>H<sub>6</sub>, the mixture was heated at reflux for 16 hr. Fractionation gave 9.9 g (84%) of clear liquid, 12, bp 110–111° (0.1 mm), which solidified on cooling, mp 54–56°. The ir (CCl<sub>4</sub>) (3000, 2950, 2280, 1860, 1775, 1695, 1610, 1575, 1480, 1350, 1310, 1280, 1255, 1080, 1045, 1010, 910, 850 cm<sup>-1</sup>) and nmr [ $\delta$  0.38 (Me\_3SiN<) and 0.45 (Me\_3SiO-) (singlets, 9 H, ratio of 1:4), 7.1-7.4 (4 H, m) ppm] spectra implied the material to be an equilibrium mixture of trimethylsilyl 2-isocyanatobenzoate (12a) and N-trimethylsilylisatoic anhydride (12b), with the latter compound composing the crystalline phase.

Calcd for C<sub>11</sub>H<sub>13</sub>NO<sub>3</sub>Si: C, 56.14; H, 5.57; N, 5.95. Anal.

Found: C, 56.39; H, 5.29; N, 5.60. Isatoic Anhydride.—Treatment of 3.0 g (13 mmol) of 12 with 20 ml of 95% EtOH gave a solution which was evaporated to dryness on the steam bath. The residue was recrystallized from ethyl acetate to give 2.2 g (91%) isatoic anhydride 13: -mp 250-252° (lit.<sup>16</sup> mp 243° dec; ir (mull) 1760, 1723 cm<sup>-1</sup>.

Reaction of TMSA with Cyclohexane-1,2-dicarboxylic Anhydride.—A solution of 23.1 g (0.15 mol) of cyclohexane-1,2-dicarboxylic anhydride (Aldrich) in 60 ml of mesitylene was treated with 0.13 mol of TMSA over 2 hr. After the mixture stirred for 3 hr at 145° (oil bath), volatiles were removed by evaporation at reduced pressure. Fractionation afforded 26.4 g (84%) of trimethylsilyl cis-2-isocyanatocyclohexanecarboxylate, bp 90–92° (0.02 mm). The ir (film) [2245 (s), 1850 (w), 1785 (m), 1710 (s), 1250, 1210, 1078, 1025, 942, 842 cm<sup>-1</sup>] and nmr  $[\delta 0.28 (9 H, s), 1.2-2.1 (8 H, m), 2.41 (1 H, d of t, J = 11, 4)$ Hz, HCCO<sub>2</sub>Si), 3.13 (0.2 H, m, HCNSi), 4.20 (0.8 H, d of d, J = 5, 4 Hz, HCNCO) ppm] spectra implied the presence of a minor amount of the N-carboxyanhydride tautomer.

Anal. Calcd for  $C_{11}H_{19}NO_3Si$ : C, 54.74; H, 7.93; N, 5.80. Found: C, 55.38; H, 8.10; N, 5.68.

Reaction of TMSA with Succinic Anhydride.—A solution of 20  $\mathbf{g}$  (0.2 mol) of succinic anhydride in 100 ml of mesitylene was heated to 145° while 0.15 mol of TMSA was added over 2 hr. The mixture was stirred for 3 hr at  $145^{\circ}$ . After removal of volatiles, fractionation afforded 20.1 g (72%) of trimethylsilyl  $\beta$ -isocyanatopropionate: colorless oil; bp 59° (0.3 mm) [lit.<sup>7</sup> bp 56–57° (1 mm)]; ir (film) 2245, 1763, 1708, 1365, 1249, 1192, 883, 843 cm<sup>-1</sup>; nmr  $\delta$  0.28 (9 H, s), 2.56 (2 H, t, J = 6.2 Hz), 3.50 (2 H, t, J = 6.2 Hz) ppm.

Reaction of TMSA with Butyric Anhydride.-Butyric anhydride (15.8 g, 0.1 mol, MC & B) in 30 ml of mesitylene was treated dropwise with 11.5 g (0.1 mol) of TMSA over 10 min. The mixture was stirred for 17 hr at 75° and evolved  $\sim 21$ . of  $N_2$ . The reaction flask was fitted with a 12-in. glass helices column. Fractionation gave 6.9 g (81%) of propyl isocyanate [bp 85-87°, ir spectrum (film) identical with that of an authentic sample] and 14.1 g (88%) of trimethylsilyl butyrate [bp 144-145° (lit.<sup>i7</sup> bp 144°); ir (film) 2950, 1723, 1264, 1253, 1093, 947, 931, 848 cm<sup>-1</sup>]

Reaction of TMSA with N-Methylmaleimide.-To a solution of 20 mmol of N-methylmaleimide in 40 ml of mesitylene was added 21 mmol of trimethylsilyl azide. The mixture, heated at reflux 56 hr, evolved 400 ml of  $N_2$ . The reaction mixture was filtered from 0.10 g of tan powder and fractionated to afford 2.3 g (58%) of 2-trimethylsilylamino-N-methylmaleimide (15): yel-(35%) of 2-crimentyishytamino-N-methyimaleimide (15): yellow oil; bp 85-87° (0.025 mm); mp 69-71°; ir (CCl<sub>4</sub>) 3390, 3345, 1775, 1715, 1630, 1440, 1390, 1260, 1125, 1050, 1000 cm<sup>-1</sup>; nmr  $\delta$  0.30 (9 H, s, Me<sub>3</sub>Si), 2.90 (3 H, s, CH<sub>3</sub>N<), 4.92 (1 H, s, HC=C<), 5.05 (1 H, broad, >NH) ppm. Anal. Calcd for C<sub>8</sub>H<sub>14</sub>N<sub>2</sub>O<sub>2</sub>Si: C, 48.41; H, 7.13; N, 14.13. Found: C 48 15; H 6 06; N 14 22

Found: C, 48.15; H, 6.96; N, 14.23.

2-Amino-N-methylmaleimide (16).-The silylated maleimide 15 was heated at reflux 5 min in 95% EtOH. Removal of volatiles by evaporation at reduced pressure and recrystallization from benzene-heptane afforded a quantitative yield of 2-amino-N-methylmaleimide: yellow crystals; mp 119-121°; ir (CHCl<sub>3</sub>) 3570, 3455, 1775, 1715, 1660, 1465, 1380, 1240, 1135, 1045 cm<sup>-1</sup>; nmr (CDCl<sub>3</sub>) & 2.82 (3 H, s) and 4.97 (1 H, s); nmr (DMSO-d<sub>6</sub>)  $\delta$  2.75, 4.73, 7.1 (2 H, broad,  $-NH_2$ ) ppm.

Anal. Calcd for  $C_5H_6N_2O_2$ : C, 47.62; H, 4.80; N, 22.21. bund: C, 47.73; H, 4.89; N, 21.97. Found:

When N-methylmaleimide and TMSA were heated without solvent at 100° until refluxing ceased (2-3 hr) and then heated a further 56 hr at 145° (oil bath), and the reaction mixture was worked up with 95% ethanol as above, 16 was isolated in 43%yield, mp 118-120°

Reaction of TMSA with N-Phenylmaleimide. A. In Xylene.-A mixture of 50 mmol each of TMSA and N-phenylmaleimide was heated at reflux for 16 hr in 25 ml of xylene (dried over sieves). The solvent was removed by evaporation at reduced pressure, and the residue was boiled with 50 ml of EtOH. Cooling and filtration afforded 10.0 g (93%) of 4,5-(N-phenyl-dicarboximido)-1,2,3-triazoline (18, R = Ph; R' = H): mp 185°; ir (CCl<sub>4</sub>) 3300, 1720, 1500, 1460, 1195 cm<sup>-1</sup>; nmr (DMSO $d_6$ )  $\delta$  4.70 and 5.60 (doublets, J = 10 Hz, HCNSi and HCN=N), 7.08-7.59 (5 H, m), 11.50 (s, >NH) ppm.

Anal. Calcd for C<sub>10</sub>H<sub>8</sub>N<sub>4</sub>O<sub>2</sub>: C, 55.55; H, 3.73; N, 25.91. Found: C, 55.47; H, 3.79; N, 25.62. B. In Nonane.—The reactants (50 mmol each) were heated

at reflux for 20 hr in 125 ml of n-nonane (bp 145°), during which time  $N_2$  was evolved and an orange oil beaded on the walls of the flask. Xylene (20 ml) was added; the mixture was cooled, then filtered, and evaporated to give an orange gum. Extraction of the gum with refluxing heptane and cooling of the extracts gave semicrystalline material which was chromatographed on Merck alumina. Elution of the vellow band with CHCl<sub>3</sub> afforded, after recrystallization from benzene-heptane, 2.0 g (21%) of 2-amino-*N*-phenylmaleimide (17): squat yellow needles; mp 112 $_7$ 113°; ir (CHCl<sub>3</sub>) 3535, 3440, 1770, 1715, 1655, 1600, 1565, 1500 cm<sup>-1</sup>; nmr  $\delta$  5.03 (1 H, s), 5.16 (2 H, broad,  $-NH_2$ ), 7.35 (5 H, s) ppm, Anal. Caled for C<sub>10</sub>H<sub>8</sub>N<sub>2</sub>O<sub>2</sub>: C, 63.82; H, 4.29; N, 14.89. Found: C, 63.97; H, 4.15; N, 14.77.

17 Could also be prepared by thermolysis of 18. A mixture of 1.5 g (7 mmol) of triazoline 18 and 25 ml of Ph<sub>2</sub>O evolved N<sub>2</sub> when stirred for 30 min at 200°. After removal of 20 ml of solvent by distillation at reduced pressure and addition of 50 ml of  $\rm Et_2O$ , filtration afforded 0.3 g (20%) of unreacted 18. The filtrate was evaporated at reduced pressure to leave an orange gum which was chromatographed as above to give 0.70 g (68%) of 17, mp 112-113.5°.

N-Butylisomaleimide.-By the method of Pyriadi and Harwood.<sup>13</sup> N-butylmaleamic acid (from maleic anhydride and nbutylamine), acetyl chloride, and triethylamine gave 64% N-butylisomaleimide (20), bp  $62^{\circ}$  (1 mm),  $\nu_{C=0}$  1800 cm<sup>-1</sup>.

**Reaction of TMSA with N-Butylisomaleimide.**—A mixture of 25 g (0.16 mol) of isomaleimide 20, 18.7 g (0.16 mol) of TMSA, and 20 ml of mesitylene was stirred at  $110^{\circ}$  until N<sub>2</sub> evolution ceased (16 hr). Fractionation of the brown oil left by removal of the volatiles in vacuo gave 19.2 g (64%) of a yellow oil, bp 99-101° (0.08 mm), which solidified on standing to a waxy solid, 1-trimethylsilyl-3-n-butyluracil (21): ir (CCl<sub>4</sub>) 3350, 3150, 3060, 1703, 1690, 1627, 1440, 1407, 1363, 1251, 1045, 842 cm<sup>-1</sup>; nmr $\delta\,0.44$  (9 H, s), 0.92 (3 H, t), 1.2–1.5 (4 H, m), 3.82 (2 H, t,  $-CH_2CH_2N <$ ), 5.60 (1 H, d, J = 7.5 Hz), 6.98 (1 H, d, J =

7.5 Hz, HC=CC=O) ppm. Anal. Caled for  $C_{11}H_{20}N_2O_2Si$ ; C, 54.96; H, 8.39; N, 11.65. Found: C, 55.17; H, 8.20; N, 11.75.

A freshly distilled sample of the yellow oil showed  $\nu_{N-C-O}$  $(CCl_4)$  at 2225 (m) cm<sup>-1</sup>, indicating the presence of some isocyanate, at least in fresh samples of 21.

3-Butyluracil (22).—Anhydrous HCl was bubbled through an ether solution of 21 for 15 min. Removal of the Et<sub>2</sub>O by evaporaettel sontanto 2110 10 mil. Tremoval of yellow crystals, which after two recrystallizations from MeOH-H<sub>2</sub>O afforded 80% 3-*n*-butyluracil (22): mp 150-151° (lit.<sup>18</sup> mp 152°); ir (CHCl<sub>3</sub>) 3350, 3150, 3060, 1718, 1650, 1443, 1420, 808 cm<sup>-1</sup>; mm  $\delta$  0.94 (3 H, t), 1.1-1.95 (4 H, m), 3.92 (2 H, t), 5.76 (1 H, d, J = 8

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Hz), 7.20 (1 H, d, J = 8 Hz), 10.48 (1 H, broad, >NH) ppm;  $\lambda_{max}^{H2}$  257 nm (ε 6600),  $\lambda_{max}^{H0-2}$  287 nm (ε 10,000). Anal. Caled for C<sub>8</sub>H<sub>12</sub>N<sub>2</sub>O<sub>2</sub>: C, 57.13; H, 7.19; N, 16.65. Found: C, 56.94; H, 7.04; N, 16.43.

Registry	No1	, 34314-62	2-0; 4	34314-	63-1;	12a,
34314-64-2;	12b,	24314-65-	3; 15	, 34314	-66-4;	16,
34314-67-5;	17, 34	314-68-6;	18 (R	= Ph;	$\mathbf{R'} =$	H),
34314-69-7;	20,	27396-39-0	: 21,	34314-	71-1:	22,

28-289-95-4; trimethylsilyl cis-2-isocyanoatocyclohexanecarboxylate, 34314-733; trimethylsilyl  $\beta$ -isocyanatopropionate, 21655-05-0; trimethylsilyl butyrate, 16844-99-8; TMSA, 4648-54-8.

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# Dichloromaleimide Chemistry. I. Substituent Effects on Carbon-13 Nuclear Magnetic Resonance and Mass Spectra

HOWARD M. RELLES\* AND ROBERT W. SCHLUENZ

General Electric Research and Development Center, Schenectady, New York 12301

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Eight N-aryldichloromaleimides (aryl = p-MeOC<sub>6</sub>H<sub>4</sub>, p-PhOC<sub>6</sub>H<sub>4</sub>, p-MeC<sub>6</sub>H<sub>4</sub>, p-PhC<sub>6</sub>H<sub>4</sub>, Ph, p-ClC<sub>6</sub>H<sub>4</sub>, m-ClC<sub>6</sub>H<sub>4</sub>, p-NCC<sub>6</sub>H<sub>4</sub>) were prepared from the appropriate aniline derivative and dichloromaleic andydride in HOAc.

Depending on the reaction conditions used, N-arylmaleimides or N-arylisomaleimides can be prepared from substituted anilines and maleic anhydride *via* the corresponding maleamic acids.<sup>1</sup>

Several authors have reported that the analogous reaction of substituted anilines with dichloromaleic anhydride produced N-aryldichloromaleimides  $1.^2$  However, no evidence was presented to firmly establish that the products obtained were indeed the dichloromaleimides 1 and not the corresponding dichloroisomaleimides 2.



We have prepared a series of eight such imides from the appropriate aniline derivatives and dichloromaleic anhydride in acetic acid. It was not possible to make definitive structural assignments for the members (a-h) of this series using proton-nmr and mass spectrometry, elemental analysis, or it spectroscopy, although the latter did favor 1a-h over 2a-h. Further structural proof was therefore sought using Fouriertransform,  $1^{3}$ C nmr spectroscopy. One would expect to find only *two* kinds of carbon atoms in the imide rings of 1 while *four* kinds would be expected in the isoimide rings of 2.

It was found that each <sup>13</sup>C nmr spectrum showed two kinds of carbon atoms for the imide ring and the appropriate number and kind of carbon atoms in the Naryl substituent (Table I). The C-Cl and C=O carbon atoms are little affected by remote substituents in the N-aryl ring and thus occur within very narrow ranges, 133.1-134.2 and 162.9-163.4 ppm, respectively. The former were readily distinguishable from nearby aromatic peaks because of their relatively low intensity resulting from a diminished nuclear Overhauser effect and the chlorine quadrupole broadening effect. It should be noted that these ranges are very close to the values for the corresponding kinds of carbon atoms in dichloromaleic anhydride, 135.9 and 159.7 ppm, respectively. These spectra leave little doubt that the correct structures are 1a-h.

A most interesting substituent effect was observed for the aromatic carbon atoms attached to the imide nitrogens. An excellent correlation was found by plotting the <sup>13</sup>C chemical shifts of these carbon atoms against  $\sigma^+$  for the substituents on the aromatic ring<sup>3</sup> (see Figure 1 and Table I); the correlation coefficient was 0.985.

It has recently been shown<sup>4</sup> that <sup>13</sup>C chemical shifts for aromatic ring carbon atoms do correlate quite well with calculated electron densities which, to some extent, are reflected by substituent parameters. It should be pointed out that a similar plot in the present example vs.  $\sigma$  gave a correlation coefficient of only 0.895. A similar difference in  $\sigma^+$  and  $\sigma$  correlation coefficients was reported for the para carbons in monosubstituted benzences.<sup>4</sup>

A study of the mass spectral rearrangements and cleavages of 1a-h also proved to be very interesting. Reports have appeared in recent years indicating that a major path in the electron impact induced cleavage of N-substituted phthalimides and N-phenylmaleimide involved the loss of carbon dioxide from the molecular

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