Organic *N*-Halogen Compounds. X.[1] Preparative Studies on *N*-Benzimidoylsulfilimines

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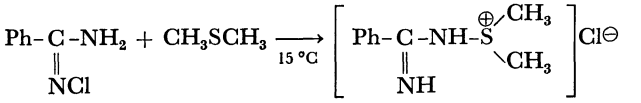
N-Chlorobenzamidine (**1**) reacted readily with dimethyl sulfide to form *N*-benzimidoylaminodimethylsulfonium chloride (**2**). Treatment of **2** with sodium hydroxide gave *N*-benzimidoyl-*S*,*S*-dimethylsulfilimine (**3**) quantitatively. The thermolysis of acyl derivatives of **3** gave rise to 1,2,4-oxadiazoles. *N*-Chloro derivative (**6**) prepared by treating **2** with sodium hypochlorite, reacted with potassium thiocyanate to form *N*-(3-phenyl-1,2,4-thiadiazolyl-5-yl)-*S*,*S*-dimethylsulfilimine (**7**).

Sulfilimines, unique in reactivity, are useful for organic synthesis. Many studies on them have been reported, but they deal with the stable *N*-sulfonyl and *N*-acysulfilimines. We wish to report the preparation of a new class of sulfilimines stabilized by an imino group together with some interesting reactions of acyl and *N*-halogen derivatives of *N*-benzimidoyl-*S*,*S*-dimethylsulfilimine, **3**.

Results and Discussion

Preparation of N-*Benzimidoylaminodimethylsulfonium Chloride (2).* *N*-Halogen compounds react readily with sulfides to form sulfonium salts.[2,3] We investigated the possible formation of such a sulfonium salt from *N*-chloroamidine and sulfide in various solvents. *N*-Chlorobenzamidine (**1**) reacted readily with dimethyl sulfide to form sulfonium chloride (**2**). Acetonitrile was found to be the most suitable solvent for the formation of **2**. When the concentration of **1** was high, the yield of **2** increased considerably. Compound **1** did not react with ethyl phenyl sulfide. The results are summarized in Table 1.

Table 1. Preparation of sulfonium salt (**2**)

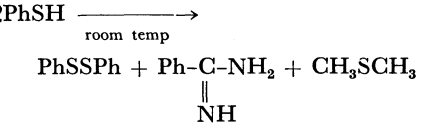


Solvent (ml)	Reaction time (h)[a]	Yield (%)
EtOEt (20)	2.0 (—)[b]	52
CH_2Cl_2 (20)	1.5 (1.0)	62
CH_3CN (20)	1.0 (0.3)	72
CH_3CN (10)	1.0 (0.3)	84

20 mmol scale.
a) Active chlorine disappeared. b) Active chlorine did not disappear.

Preparation of N-*Benzimidoyl*-S,S-*dimethylsulfilimine (3).* Treatment of **2** with aqueous sodium hydroxide gave **3** quantitatively. Treatment of **3** with dry hydrogen chloride afforded the starting material, **2**. The new sulfilimine, **3**, which could be recrystallized from chloroform–ether, melts at 67—68 °C. Sulfilimine **3** is strongly hygroscopic and soluble in common organic solvents except for hydrocarbons. It was found that **3** is quite stable under reflux in tetrahydrofurane for 3 h but decomposes evolving dimethyl sulfide under reflux in xylene for 2 h.

However, the S–N bond of **3** was found to cleave easily on being treated with benzenethiol.



Structure of 3. The structures of **2** and **3** are discussed on the basis of spectral data as follows. In the IR spectra[4] the C=N streching vibration of **2** is at 1650 cm^{-1}, that of **3** at 1510 cm^{-1}. The shift is analogous to that observed in the case of a carbonyl group attached to a ylide carbon or ylide nitrogen atom— (a).

In the UV spectra, **2** and **3** have the same λ_{max} (239 nm) but ε_{max} of **3** (11300) is by 2100 larger than that of **2**— (b).

In the NMR spectra,[5] the resonance of protons to the positively charged sulfur atom and the nitrogen atom shifts upfield by 0.3 and 3.5 ppm, respectively, in going from **2** to **3**— (c).

(a) and (c) suggest that form (**3a**) is a contributor to the sulfilimine structure. (b) and (c) suggest that the S–N bond posesses a partial double bond character due to 2p—3d orbital overlap, (**3b**).

The overall structure can be represented by (A).

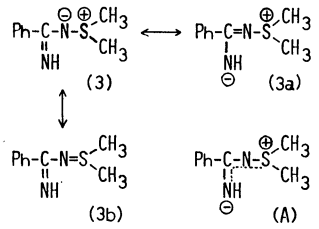
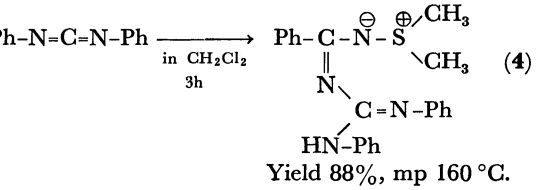


Fig. 1.

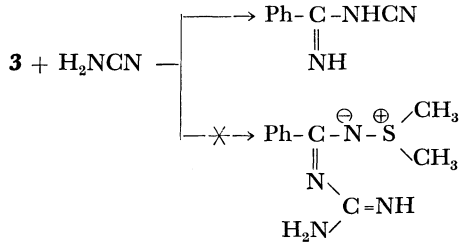
These resonance forms can contribute to the stabilization of this new type sulfilimine.

Amidino and Acyl Derivatives of 3. Addition of **3** to diphenylcarbodiimide occurred easily at low temperature to afford amidino derivative (**4**) in a good yield.



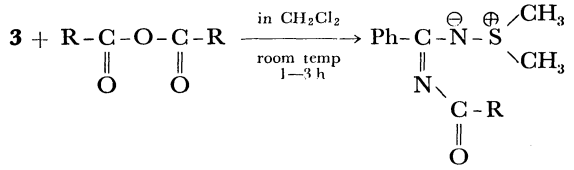
Yield 88%, mp 160 °C.

Cyanamide, which seems to be carbodiimide, did not react with **3** at room temperature, but gave *N*-cyanobenzamidine in 60% yield under reflux in tetrahydrofuran for 30 min.



Detailed mechanism has not been clarified yet. The reaction path might be similar to that proposed in the formation of cyanoamidine from amidine and cyanamide.[6]

Acyl derivatives of **3** were easily prepared by the treatment of **2** with acid anhydride.



5a: R=Ph
5b: R=*p*-$CH_3C_6H_4$
5c: R=CH_3

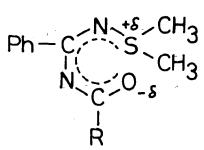
The results and physical properties of **5** are given in Table 2.

Table 2. Physical properties of **5**

Compounds	Yield (%)	Mp (°C)	IR (cm^{-1}) $\nu_{C=N}$	IR (cm^{-1}) $\nu_{C=O}$	UV λ_{max} (ε)
5a	66	188—190	1600	1570	245 (11700)
5b	54	172—173	1590	1550	251 (18600)
5c	60	114—116	1620	1600	230 (10800)

These sulfilimines have relatively high melting points and are soluble in common organic solvents except for ether and hydrocarbons.

In the IR spectra, the C=N absorption of **5** is at a shorter wavelength than that of **3**. On the other hand, the C=O absorption is at a longer wavelength than that of normal amide absorption. In view of these shifts in the IR spectra, the structure of **5** can be represented by (B).

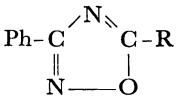


(B)

Fig. 2.

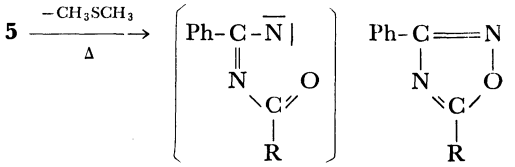
The mass spectrum of **5a** revealed that the primary fragmentation is loss of dimethyl sulfide. Thus, it was expected that 1,2,4-oxadiazole would be formed by elimination of dimethyl sulfide. In fact, heating of **5a** and **5b** without solvent in test tubes at about 200 °C gave rise to 1,2,4-oxadiazoles. However, **5c** gave no corresponding product. The structures of these products were confirmed by elemental analyses and IR spectra. The results are given in Table 3.

Table 3. Formation of 1,2,4-oxadiazoles

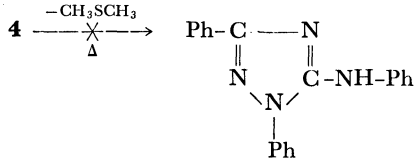


R	Reaction temp (°C)	Reaction time (min)	Yield (%)	Mp (°C)
Ph	200—210	10	70	108 (108)[18]
p-$CH_3C_6H_4$	190—200	20	63	121—122
CH_3	160	5	0	—

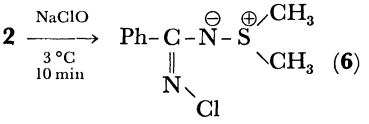
Detailed mechanism of this interesting internal ring formation has not been clarified. The thermolysis seems to proceed *via* a nitrene in view of oxadiazole formation from dimethyl diazidomalonate[7] and *N*-benzoyl-*N'*-chloroamidino compounds.[8,9]



Amidino derivative **4** was also expected to form 1,2,4-triazole by thermolysis. However, no cyclization occurred.

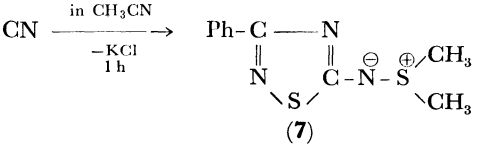


Preparation and Reaction of N-*Chloro Derivative of* **3**. Sulfilimines are stabillized by an electron-withdrawing group attached to the ylide nitrogen atom. Attempts were made to prepare *N*-halogen derivative of **3**. The *N*-chlorosulfilimine (**6**) could easily be prepared quantitatively by treatment of **2** with sodium hypochlorite at low temperature.



The sulfilimine **6** which can be recrystallized from chloroform–petroleum ether is relatively stable, its melting point being 98—99 °C (with decomposition).

N-Haloamidino compounds readily react with potassium salts of thiocyanic acid and Cyanoiminothiocarbonic acid to give thiadiazoles[10–12] and Δ^4-1,2,4-thiadiazolines[13–16] in good yields. We investigated the reaction of **6** with potassium thiocyanate. The ex-



(7)

Yield 68%, mp 168—169 °C.

othermic reaction proceeded immediately in acetonitrile to afford *N*-(3-phenyl-1,2,4-thiadiazolyl-5-yl)-*S*,*S*-dimethylsulfilimine (**7**).

The structure of **7** was determined from the following.

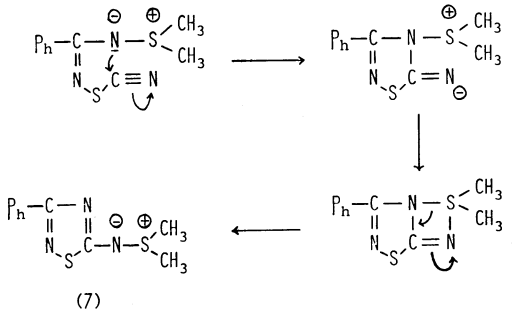
(a) No absorption of a thiocyanate group was observed in the IR spectrum.

(b) The analytical values of **7** and its picrate are in good agreement with their theoretical ones.

(c) UV and NMR data.

The formation of **7** might proceed as in the following scheme. The S–N bond was initially formed, internal ring formation being then followed by migration of the dimethylsulfonio group to yield **7**.

No such migration of a sulfonio group in sulfilimine is known.



(7)

Scheme 1.

Experimental

The melting points are uncorrected. IR spectra were taken with a Hitachi EPI-S2 spectrometer. NMR spectra were recorded at 60 MHz with a Hitachi R-24A spectrometer, and the chemical shifts were given in δ-values, TMS being used as an internal standard. Mass spectra were taken with a JEOL-D100 mass spectrometer. UV spectra were taken in methanol with a Hitachi 624 spectrometer.

N-Chlorobenzamidine (**1**) was prepared by the method[17] described previously.

*N-Benzimidoylaminodimethylsulfonium Chloride (**2**).* A solution of **1** (20 mmol) in acetonitrile (5 ml) was added drop by drop to a stirred solution of dimethyl sulfide (24 mmol) in acetonitrile (5 ml). The temperature was maintained below 15 °C during the reaction. After stirring for *ca.* 0.3 h, active chlorine disappeared and sulfonium salt precipitated. The solid was separated by filtration and washed with acetonitrile; yield, 84%; mp 183 °C. Recrystallization from ethanol gave a pure product; mp 183—183.5 °C (Found: C, 49.37; H, 5.76; N, 12.90%. Calcd for $C_9H_{13}N_2SCl$: C, 49.88; H, 6.05; N, 12.93%). Picrate: mp 152—153 °C (from water). (Found: C, 44.15; H, 3.62; N, 17.15%. Calcd for $C_{15}H_{15}N_5SO_7$: C, 44.01; H, 3.69; N, 17.11%).

The reaction when carried out in ether and dichloromethane in a similar way gave **2** in 52 and 62% yields, respectively.

*N-Benzimidoyl-S,S-dimethylsulfilimine (**3**).* 2M sodium hydroxide (50 ml) was added to a stirred solution of **2** (70 mmol) in water–chloroform (20—70 ml) at a temperature below 5 °C. After the chloroform layer was separated, residual **3** was extracted twice with 15 ml portions of chloroform. The combined extracts were dried (Na_2SO_4), filtered, and evaporated under reduced pressure. The residual needles were wahsed with ether and separated by filtration under nitrogen atmosphere; yield, quant; mp 65—67 °C. Recrystallization from chloroform–ether gave the pure sulfilimine; mp 67—68 °C. (Found; N, 15.70%. Calcd for $C_9H_{12}N_2S$: N, 15.54 %). *m/e* 180 (M^+).

*Reaction of **3** with Cyanamide.* A mixture of **3** (10 mmol) and cyanamide (10 mmol) in THF (10 ml) was refluxed for 30 min. The reddish reaction mixture was treated with active carbon and was concentrated under reduced pressure. The remaining sirup was dissolved in hot chloroform. Ether was then added. After cooling, the resulting crystals were separated from solution by filtration, and the filtrate was evaporated. The remaining oily material was crystallized from 2 M hydrochloric acid. The total yield of *N*-cyanobenzamidine was 60%; mp 141 °C (from ethanol–water; Ref. 6 mp 141—142 °C).

*N-(N-Benzoylbenzimidoyl)-S,S-dimethylsulfilimine (**5a**).* A solution of benzoic anhydride (22 mmol) in dichloromethane (8 ml) was added to a stirred solution of **3** (20 mmol) in dichloromethane (7 ml) at 20—25 °C. After completion of addition, crystals precipitated. After 1 h of continued stirring, the precipitated crystals were separated by filtration and the filtrate was concentrated. The remaining oily material was washed with 2M sodium hydroxide (10 ml) and ether to give crystals of **5a**. The total yield of **5a** was 66%; mp 188—190 °C (from chloroform–ether). (Found; C, 67.36; H, 5.70; N, 9.70%. Calcd for $C_{16}H_{16}N_2OS$: C, 67.58; H, 5.67; N, 9.85%). *m/e* 284 (M^+). NMR (DMSO-d_6): 2.91 (s, CH_3S) and 7.20—8.15 (m, $C_6H_5C{=}O$, $C_6H_5C{=}N$).

*N-(N-p-Tolylbenzimidoyl)-S,S-dimethylsulfilimine (**5b**).* This was synthesized by the same procedure. Yield, 54%; mp 172—173 °C (from chloroform–ether). (Found: C, 68.03; H, 6.13; N, 9.10%. Calcd for $C_{17}H_{18}N_2OS$: C, 68.43; H, 6.08; N, 9.39%). *m/e* 298 (M^+). NMR (DMSO-d_6): 2.87 (s, CH_3S), 2.33 (s, $CH_3C_6H_4$), and 7.13—7.96 (m, C_6H_5, $CH_3C_6H_4$).

*N-(N-Acetylbenzimidoyl)-S,S-dimethylsulfilimine (**5c**).* Acetic anhydride (17 mmol) and **3** (15 mmol) were stirred in dichloromethane (13 ml) in the presence of sodium carbonate (8.5 mmol) at room temperature for 1 h. After the reaction mixture had been poured into water, the oily layer was separated. The aqueous layer was then extracted twice with 7 ml portions of dichloromethane. After the combined extracts had been dried over sodium sulfate, the solvent was removed by concentration. The remaining oily material was crystallized from ether; yield, 60%; mp 114—116 °C (from dichloromethane–ether). (Found: C, 59.60; H, 6.01; N, 12.51%. Calcd for $C_{11}H_{14}N_2OS$: C, 59.43; H, 6.35; N, 12.60%). NMR (DMSO-d_6): 2.72 (s, CH_3S), 2.02 (s, CH_3-O), and 7.17—7.75 (m, C_6H_5). *m/e* 222 (M^+).

3,5-Diphenyl-1,2,4-oxadiazole. Sulfilimine **5a** was heated in a test tube in an oil-bath at 200—210 °C for 10 min. Evolution of dimethyl sulfide was observed. The contents of the tube were cooled, and the resulting crystals were dissolved in ether. After being treated with active carbon and concentrated to dryness, the remaining crystals were purified by washing with a small amount of aqueous ethanol. Yield, 70%; mp 108 °C (from aqueous ethanol; Ref. 18 mp 108 °C)

3-Phenyl-5-p-tolyl-1,2,4-oxadiazole. After heating **5b** at 190—200 °C for 20 min and then cooling, the contents were dissolved in ether. Treatment of the solution with active carbon and concentration under reduced pressure gave needle-like crystals. Yield, 63%; mp 121—122 °C (from ethanol–water). (Found: C, 76.15; H, 5.08; N, 11.49%. Calcd for $C_{15}H_{12}N_2O$: C, 76.25; H, 5.12; N, 11.86%). *m/e* 236 (M^+).

*N-(N-Chlorobenzimidoyl)-S,S-dimethylsulfilimine (**6**).* Sodium hypochlorite (40 mmol) was added to a stirred solution of **2** (36 mmol) in water (20 ml) and dichloromethane

(25 ml) below 3 °C. After stirring for 10 min, the oily layer was separated, and the aqueous layer was extracted with dichloromethane (10 ml). The combined extracts were dried over sodium sulfate, filtered, and concentrated under reduced pressure. The remaining oily substance was crystallized from ether. Yield, 92%; mp 98—99 °C (from chloroform–petroleum ether). (Found: C, 50.05; H, 5.26; N, 13.25%. Calcd for $C_9H_{11}N_2SCl$: C, 50.35; H, 5.16; N, 13.05%). UV: λ_{max} 217 nm (ε: 14000). *m/e* 214 (M^+).

N-*5-(Phenyl-1,2,4-thiadiazoyl)*-S,S-*dimethylsulfilimine (7)*. A solution of **6** (7 mmol) in acetonitrile (4 ml) was added to a stirred suspension of potassium thiocyanate (8 mmol) in acetonitrile (6 ml) with cooling in an ice-bath. A violent exothermic reaction took place, the solution turning yellow. After stirring at room temperature for 1 h, insoluble matter was removed by filtration. A yellowish oily substance was obtained by concentrating the filtrate under reduced pressure. The oil was crystallized from ether and the resulting crystals were collected, yield, 68%. Recrystallization twice from dichloromethane–ether gave pure **7**; mp 168—169 °C. (Found: C, 50.35; H, 4.69; N, 17.88%. Calcd for $C_{10}H_{11}N_3S_2$: C, 50.61; H, 4.67; N, 17.70%). UV: λ_{max} 248 nm (ε: 34000). NMR (DMSO-d_6): 2.88 (s, CH_3S), 7.32—8.15 (m, C$_6H_5$). *m/e* 237 (M^+). Picrate: mp 176 °C (from water). (Found: C, 40.93; H, 2.95; N, 18.06%. Calcd for $C_{16}H_{14}N_6O_7S_2$: C, 41.20; H, 3.03; N, 18.02%).

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4) (**2**): νNH 3250, 3300 cm^{-1}. (**3**): νNH 3300^{-1}.

5) (**2**): δ=3.03 (s, CH_3SCH_3), 9.00 (s, N*H*), 7.40—7.95 (m, C$_6H_5$). (**3**): δ=2.74 (s, CH_3SCH_3), 5.05 (s, N*H*), 7.15—7.95 (m, C$_6H_5$).

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