The Synthesis and Properties of Aliphatic Sulfonamide Methylimines and Bis(methylimines)

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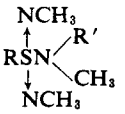
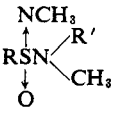
Abstract: The reaction of aliphatic mercaptans with methylchloramine has been found to yield N-methylalkanesulfonamide bis(methylimines) Ia in *ca.* 65% yields. The bis(methylimines) hydrolyze with surprising ease to produce the corresponding sulfonamide methylimines IIa. N,N-Dimethylmethanesulfonamide bis(methylimine) was found to hydrolyze *exclusively* by amide S–N bond cleavage. Hydrolysis *via* protonation on the weakly basic amide nitrogen is proposed to explain the results. Like related imines, these sulfonamide derivatives are weakly basic. Those having an N–H bond are also somewhat acidic, as evidenced by their facile reaction with sodium hydride. The N–H protons are exceedingly mobile, according to low-temperature nmr studies.

Sulfone diimines, $R_2S(NH)_2$, are a recently discovered[1] class of molecules that are structurally analogous to sulfones, but differ in that the semipolar S→O bonds are replaced by S→N. Related S→N compounds are conceivable in other functional groups containing the $-SO_2-$ moiety, such as the sulfonamide group. This paper reports the syntheses and some properties of alkanesulfonamide bis(methylimines) I and methylimines[2] II. Compounds of type I appear to be completely new structures. The simple aliphatic compounds of type II reported herein are also new. However, cyclic[3] and aromatic[4] sulfonamide imines have been prepared from sulfinamide imines, $-S(NAr)NH-$, by permanganate and bromine–water oxidations, respectively.

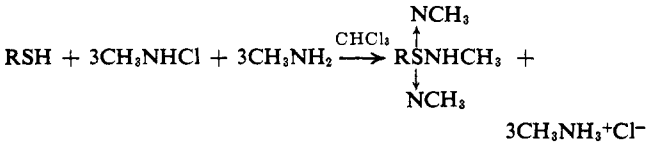


Ia, R′ = H
b, R′ = CH₃

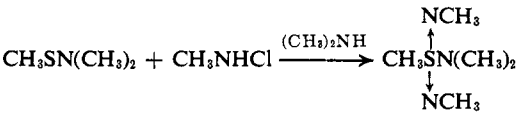


IIa, R′ = H
b, R′ = CH₃

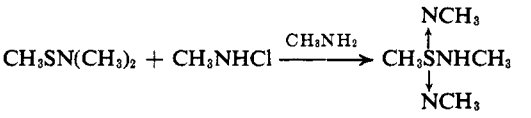
Synthesis of Sulfonamide Bis(Methylimines). These compounds of type Ia are readily isolated in *ca.* 65% yields from the reaction of aliphatic mercaptans with methylchloramine[5] in the presence of excess methylamine. The major by-product is the disulfide derived from the mercaptan. Small amounts of N,N′-dimethylformamidine are also formed.



The synthesis undoubtedly proceeds in a stepwise fashion *via* sulfenamide and sulfinamide methylimine intermediates. If N,N-dimethylmethanesulfenamide is treated with methylchloramine, in the presence of dimethylamine as the hydrogen chloride acceptor, the N,N-dimethylsulfonamide derivative Ib (R = CH_3) may be isolated in *ca.* 20% yield. The use of dimethylamine



rather than methylamine to absorb hydrogen chloride is essential in this instance. When N,N-dimethylmethanesulfenamide is treated with methylchloramine in the same fashion as were the mercaptans, *i.e.*, in the presence of excess methylamine, only the mono-N-methylsulfonamide derivative (Ia, R = CH_3) is isolated.



This result suggests that exchange of amino groups occurs at some stage of the reaction. It is likely that this occurs at the sulfenamide stage, prior to reaction with methylchloramine.[6] Because of problems arising from the nitrogen ligand exchange reaction, compounds of type Ib are better synthesized *via* the alkylation route described later.

Although the bis(methylimines) of type Ia are best synthesized *via* the mercaptans, they were originally observed as an unexpected reaction product from an attempted synthesis of dimethylsulfone bis(methylimine), $(CH_3)_2S(NCH_3)_2$. After repeated attempts to synthesize this molecule from dimethyl sulfide and methylchloramine failed, an alternative approach *via* a three-step reaction of dimethyl sulfide with (1) chlorine, (2) methylamine, and (3) methylchloramine was attempted. From this reaction sequence only Ia (R = CH_3) was isolated, in up to 20% yields. A reasonable sequence which explains the formation of Ia is shown in eq 1–5. The sulfur-stabilized carbonium

(1) R. G. Laughlin and W. Yellin, *J. Am. Chem. Soc.*, **89**, 2435 (1967), and references therein.

(2) The nomenclature utilized in this paper is an extension of that previously suggested for the sulfone-like structures.[1] IUPAC Rule 641.9 suggests the generic names "alkanesulfonodiimidamide" and "alkanesulfonimidamide" for structures I and II, respectively.

(3) G. Kresse, C. Seyfried, and A. Trede, *Tetrahedron Letters*, 3933 (1965).

(4) H. Takei, I. Watanabe, and T. Mukaiyama, *Bull. Chem. Soc. Japan*, **38**, 1989 (1965).

(5) Methylchloramine is generated *via* the gas-phase reaction of methylamine and chlorine in the modified Sisler chloramine generator even more easily and in higher yields than is chloramine (R. G. Laughlin, *Chemiker Ztg.*, in press).

(6) Similar exchange reactions of nitrogen ligands of sulfenamides were reported recently by P. Tavs (*Angew. Chem. Intern. Ed. Engl.*, **5**, 1048 (1966)). However, attempts to exchange an $-NHCH_3$ group by $-N(CH_3)_2$ in Ib (R = CH_3) were unsuccessful and D. E. O'Connor has found that sulfinamides are similarly unreactive in attempted nitrogen ligand exchange reactions (unreported work from these laboratories).

$$(CH_3)_2S + Cl_2 \xrightarrow[CHCl_3]{-50^\circ} (CH_3)_2\overset{+}{S}Cl,\ Cl^- \quad (1)$$

$$(CH_3)_2\overset{+}{S}Cl + CH_3NH_2 \xrightarrow{-35^\circ} CH_3\overset{+}{S}{=}CH_2 + CH_3NH_3Cl \quad (2)$$

$$CH_3\overset{+}{S}{=}CH_2 + CH_3NH_2 \longrightarrow CH_3SCH_2NHCH_3 \quad (3)$$

$$CH_3SCH_2NHCH_3 \longrightarrow CH_3SH + CH_2{=}NCH_3 \quad (4)$$

$$CH_3SH + CH_3NHCl \xrightarrow{0\text{ to }40^\circ} \text{Ia } (R = CH_3) \quad (5)$$

ion intermediate is frequently mentioned in connection with the Pummerer reaction and its remarkable stability has been eloquently demonstrated by its isolation as the hexachloroantimonate salt[7] Its further reactions according to steps 3 and 4 have numerous analogies and the mercaptan, once formed, has been shown to form Ia under the reaction conditions.

Hydrolysis Reactions. The imine bonds in dialkylsulfone diimines are remarkably resistant to acid- or base-catalyzed hydrolysis.[1] Since sulfonamides are also notoriously difficult to hydrolyze, it might have been expected that the related bis(methylimine) would likewise be inert. Indeed this is the case in basic solution, *e.g.*, after 2-hr reflux in 2 *N* aqueous base. However, it was found that the bis(methylimines) are extremely prone to undergo acid-catalyzed hydrolytic cleavage. Slow hydrolysis occurs in water in the absence of added acid, and even by the action of atmospheric moisture on stored samples. Refluxing briefly with 2 equiv of acid effects quantitative hydrolysis, producing the N-methylalkanesulfonamide methylimines (IIa) and methylamine (both as salts). Thus,

$$RS(NCH_3)NHCH_3 \xrightarrow[H_2O]{H^+} RS(O)NHCH_3 + CH_3NH_2$$

the hydrolysis of the readily accessible bis(methylimines) gives in essentially quantitative yield and excellent purity the methylimines (IIa). The hydrolysis stops cleanly at the methylimine stage; no evidence for sulfonamide formation was ever obtained. In fact, *neither* N-methylmethanesulfonamide nor its methylimine undergoes detectable hydrolysis (nmr) after 10 hr at 100° in 13.9 *M* sulfuric acid—conditions under which both compounds are fully protonated.[8] No experimental evidence has been obtained which allows one to hypothesize as to the reason for the remarkable difference in hydrolytic reactivity between the mono- and the bis(methylimines).

Investigation of the hydrolysis of the N,N-dimethyl compound Ib (R = CH_3) revealed the likewise unexpected result that *only the S–N bond to the amide (three coordinate) nitrogen undergoes hydrolytic cleavage.*

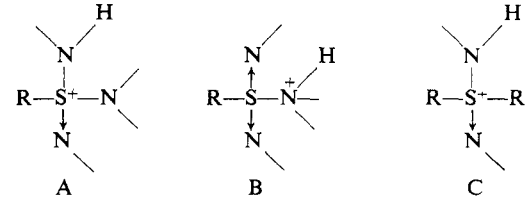
$$CH_3S(NCH_3)N(CH_3)_2 \xrightarrow[H_2O]{H^+} CH_3S(NCH_3)O + HN(CH_3)_2$$

No N,N-dimethylmethanesulfonamide methylimine (IIb, R = CH_3) could be detected by gas chromatographic techniques (<0.1%). Examination of the amines produced (in 96% yield) revealed them to be comprised of 98 mol % $(CH_3)_2NH$ and 2 mol % CH_3NH_2.[9]

(7) H. Meerwein, K.-F. Zenner, and R. Gipp, *Ann.*, **688**, 67 (1965).
(8) R. G. Laughlin, *J. Am. Chem. Soc.*, **89**, 4268 (1967).

Thus, while the high solvolytic reactivity of the sulfonamide bis(methylimines) seems at first inconsistent with the previously observed inertness of the sulfone diimines,[1] the fact is that *the imine-type S→N bonds are hydrolytically inert in both the sulfone and the sulfonamide structures.* The above results unambiguously demonstrate this to be true in the N,N-dimethyl derivative Ib. In the mono-N-methyl derivative Ia this is not provable because the same products result from either imine or amide S–N bond cleavage. However, the type Ia and Ib compounds hydrolyze with comparable ease and it would seem highly unlikely that the difference of a methyl substituent would profoundly alter the fundamental reaction process.

Comparison of the basicity of these imines (below) with that of aliphatic sulfonamides[8] leaves no doubt that the principal site of protonation of the bis(methylimines) is the imine and not the amide nitrogen (A, rather than B). However, the present results suggest



that cation B, rather than A, is the reactive intermediate in the hydrolysis. In the first place, if hydrolysis occurs *via* A it is difficult to understand the gross difference in reactivity between the sulfonamide bis(methylimines) and the sulfone diimines, since A is structurally analogous to the sulfone diimine cation C. On the other hand, protonated sulfone diimines cannot form a cation analogous to B[10] and this hydrolysis path is therefore not open to them. Secondly, the assumption that hydrolysis occurs *via* A fails to explain the extraordinary selectivity for amide S–N bond cleavage in the N,N-dimethyl derivative Ib whereas the assumption that hydrolysis occurs *via* B explains this selectivity in a straightforward manner. In form A, two of the nitrogen atoms are chemically equivalent, except for the fact that one nitrogen has two methyl substituents and the other only one. In form B, the original differentiation between amide and imine nitrogens is retained in the cation—the only assumption required being that the N-methyl groups remain immobile. In B, the protonated amide nitrogen is transformed into an excellent leaving group (a stable amine molecule) and the amide S–N bond will be weakened by the destruction of any π bonding which may have existed.[8] Hence, both the selectivity for amide S–N bond cleavage and the ease of reaction are understandable only by assuming hydrolysis *via* B. Whether the hydrolysis occurs *via* a dissociation or a displacement process has not been determined.[11]

(9) It is highly probable that the small quantity of methylamine produced was actually derived from a small amount of type Ia bis(methylimine) present in the sample, in view of the previously described difficulty with nitrogen ligand exchange in the synthesis of the N,N-dimethylsulfonamide derivatives.
(10) Cation B is of course structurally related to the neutral sulfone diimine molecule. The difference in reactivity of B and the sulfone diimines toward hydrolysis is easily understandable in terms of the enormous difference between an amine and a carbanion as a leaving group.
(11) A kinetic study of the hydrolysis of $(CH_3)_3N^+SO_3^-$, a compound rather closely related to the above-postulated intermediate, has been

Table I. Basicity of Sulfonamide Methylimines, Bis(methylimines), and Related Compounds

Compound, B	pK_a of BH^+ [a]
$CH_3S(NCH_3)_2NHCH_3$	6.62 ± 0.03
$C_2H_5S(NCH_3)_2NHCH_3$	6.88 ± 0.06
$CH_3S(NCH_3)_2N(CH_3)_2$	6.46 ± 0.01
$CH_3S(NCH_3)(O)NHCH_3$	4.39 ± 0.04
$CH_3S(NCH_3)(O)N(CH_3)_2$	3.90 ± 0.06
$CH_3SO_2NHCH_3$	−6.0[b]
$CH_3S(NH)_2CH_3$	5.59 ± 0.01[c]
$CH_3S(NH)(O)CH_3$	3.24 ± 0.02[c]

[a] A. Albert and E. P. Serjeant, "Ionization Constants of Acids and Bases," John Wiley and Sons, Inc., New York, N. Y., 1962. [b] Reference 8. [c] Reference 1.

raphy at 140° without showing signs of decomposition.

Basicity. Table I lists pK_a data obtained for type I and II compounds and for related structures. The sulfonamide imines are about one pK unit more basic than the analogous (unmethylated) sulfone derivatives. About the same difference in basicity exists between sulfonamide mono- and bis(methylimines) as between sulfone imines and diimines (2.2 *vs.* 2.4 units).

Acidity. The N–H protons in type Ia and IIa structures are noticeably acidic, as is also true of sulfonamides. Both Ia and IIa structures react rapidly and quantitatively with sodium hydride in monoglyme to

Table II. Nuclear Magnetic Resonance Data

		Assignments[a]					
	Solvent	SCH_3	$>NCH_3$	$\rightarrow NCH_3$	NH	CCH_3	Other
			Sulfonamide Bis(methylimines)				
$CH_3S(NCH_3)_2NHCH_3$	$CDCl_3$	7.17	——7.36——		2.81	...	
	D_2O	6.63	——6.99——		4.75	...	
	$(CD_3)_2SO$	6.79	——7.07——		5.13	...	
$CH_3S(NCH_3)_2N(CH_3)_2$	$CDCl_3$	7.33	7.18[b]	7.30[b]	...	...	
$CH_3S(NCH_3)_2N(C_2H_5)_2$	$CDCl_3$	7.30	6.72[c] (4; J = 7 Hz)	7.36	...	7.85 (3)	
$C_2H_5S(NCH_3)_2NHCH_3$	$CDCl_3$	6.96[d] (4; J = 8 Hz)	——7.39——		4.73	8.84 (3)	
$C_4H_9S(NCH_3)_2NHCH_3$	$CDCl_3$	6.94[d] (3; J = 8 Hz)	——7.37——		4.45	9.06 (3)	8.5[e] (mult)
$C_{12}H_{25}S(NCH_3)_2NHCH_3$	$CDCl_3$	6.96[d] (3; J = 8 Hz)	——7.37——		...	9.12 (3)	8.74[f]
			Sulfonamide Methylimines				
$CH_3S(NCH_3)(O)NHCH_3$	$CDCl_3$	7.08	——7.33——		4.49	...	
$CH_3S(NCH_3)(O)N(CH_3)_2$	$CDCl_3$	7.36	7.18	7.25[g]	...	...	
$C_4H_9S(NCH_3)(O)NHCH_3$	$CDCl_3$	7.00[d] (3; J = 8 Hz)	——7.31——		5.52	9.05 (3)	8.6 and 8.2[e] (mult)
$C_{12}H_{25}S(NCH_3)(O)NHCH_3$	$CDCl_3$	7.10[d] (3; J = 8 Hz)	——7.39——		...	9.20 (3)	8.82[f], 8.3[h] (mult)
			Sulfonamides				
$CH_3SO_2NHCH_3$	$CDCl_3$	7.10	7.28 (2; J = 5 Hz)	...	4.85	...	
	D_2O	6.48	6.80	...	...	...	
$CH_3SO_2N(CH_3)_2$	$CDCl_3$	7.27	7.19	...	...	...	
	D_2O	6.66	6.77	...	...	...	
$CH_3SO_2NHC_2H_5$	D_2O	6.57	6.45[c] (4; J = 7 Hz)	...	...	8.40 (3)	
			Sulfenamides				
$CH_3SN(CH_3)_2$	$CDCl_3$	7.82	7.34	...	...	...	
$CH_3SN(C_2H_5)_2$	$CDCl_3$	7.99	7.27[c] (4; J = 7 Hz)	...	...	8.90 (3)	
$(CH_3S)_2NCH_3$	$CDCl_3$	7.55	6.93	...	...	...	

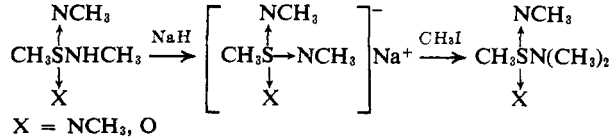
[a] Chemical shifts in τ units; TMS = 10 ppm; D_2O, capillary TMS; all others internal TMS. Multiplicity and coupling constants are indicated in parentheses where appropriate. Determined on a Varian HA-100 instrument. [b] Assigned by comparison with the N,N-diethyl analog. [c] N-Methylene. [d] S-Methylene. [e] β- and γ-methylene of the butyl group. [f] Long chain methylene. [g] Assignment between $\rightarrow NCH_3$ and SCH_3 uncertain. The τ 7.25 peak was broadened relative to the τ 7.36 peak, probably due to the N quadrupole. [h] β-Methylene.

Thermal Stability. The thermal stabilities of structures I and II parallel, in general, those of sulfone diimines and sulfone imines.[1] The bis(methylimines) Ia are distillable up through the *n*-butyl homolog (bp 107° (0.04 mm) bath at 135°). The compounds cannot be analyzed by gas chromatography; decomposition occurs in the process.

The methylimines II are significantly more stable thermally than the bis(methylimines). Compound IIa (R = CH_3) is easily analyzed by gas chromatog-

reported: I. G. Ryss and L. P. Bogdanova, *Kinetika i Kataliz*, **7**, 169 (1966); *Chem. Abstr.*, **64**, 19343 (1966). It is believed to hydrolyze *via* displacement of hydroxide ion on sulfur.

form hydrogen and the sodium salts. These salts are



cleanly alkylated by methyl iodide. In the case of Ia, methylation produces the same compound synthesized earlier *via* $CH_3SN(CH_3)_2$ and methylchloramine. From IIa, compounds of type IIb were obtained. As described previously, these are inaccessible *via* hydrolysis of type Ib compounds.

Nuclear Magnetic Resonance Properties. Table II lists the nmr properties of the various sulfonamide derivatives synthesized. The nmr spectra of Ia and IIa compounds suggest that the N–H proton is extremely mobile. In these structures all the $N-CH_3$ signals fall into a sharp singlet, whereas in Ib and IIb structures the amide and imine N-methyl signals are separated, as expected. The amide and imine resonances in Ia and IIa (R = CH_3) are not resolved down to at least $-102°$ (in methylene chloride). The facile proton transfer is consistent with the above-described amphoteric character of the compounds.

The nmr spectra of the N,N-dialkyl derivatives Ib and IIb (R = CH_3) were also carefully studied down to $-102°$ in methylene chloride. No readily exchangeable protons exist in these structures, but there is the possibility that a barrier to rotation exists about one or the other of the S–N bonds. No conclusion as to the existence of such a barrier may be reached because no splitting was observed, even in IIb where the sulfur is asymmetric. Similar experimental results have been reported in the case of N,N-dialkyl sulfinamides.[12]

Comparisons of the S-methyl chemical shift data of dimethyl sulfone with methanesulfonamides and of the imine and diimine derivatives with each other (Table III) provide further support for the proposition that

Table III. Comparison of Dimethyl Sulfone and Methanesulfonamide Derivatives

Compound, B	SCH_3 chemical shifts[a]	pK_a of BH^+
$CH_3SO_2NHCH_3$	7.10	−6.0[b,d]
$CH_3SO_2N(CH_3)_2$	7.27	−5.5[b,d]
$CH_3SO_2CH_3$	7.08[c]	−12[b,d]
$CH_3S(O)(NCH_3)NHCH_3$	7.08	4.39
$CH_3S(O)(NCH_3)N(CH_3)_2$	7.36	3.90
$CH_3S(O)(NH)CH_3$	6.90	3.24
$CH_3S(NCH_3)_2NHCH_3$	7.17	6.62
$CH_3S(NCH_3)_2N(CH_3)_2$	7.33	6.46
$CH_3S(NH)_2CH_3$	6.94	5.59

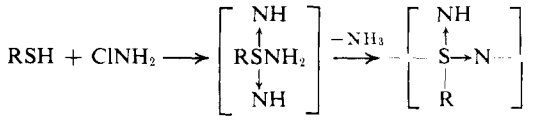
[a] From Table II. [b] Reference 8. [c] Reference 1. [d] It must be borne in mind that the sulfonamides protonate on N rather than O.[8] The difference in the basicity of oxygen between the sulfonamides, and the sulfone is therefore less than the numbers indicate, and conceivably the positions could even be reversed.

significant π bonding exists in the sulfonamide type of S–N bond.[8] Replacement of S-methyl by either $NHCH_3$ or $N(CH_3)_2$ in each of the three series causes either little change or an *upfield* shift of the remaining S-methyl group. This is an opposite effect to that produced by "substitution" of nitrogen for carbon in saturated molecules ($-CH_2CH_2-$ *vs.* $-CH_2N<$), and is indicative of electron donation by the sulfonamide nitrogen.

The basicity data listed in Table III likewise suggest a degree of π bonding in sulfonamide S–N bonds, since replacement of S-alkyl by amine groups *increases* the basicity slightly. An analogous effect is seen in comparing methyl ketones with carboxylic amides.[13] The latter are more basic, presumably because electron donation to the carbonyl oxygen thru C–N π bonding more than compensates for the electron-withdrawing nature of nitrogen relative to carbon.

(12) R. M. Moriarty, *J. Org. Chem.*, **30**, 600 (1965).
(13) E. M. Arnett, *Progr. Phys. Org. Chem.*, **1**, 339, 374 (1963).

Reactions of Mercaptans with Chloramine. While methylchloramine reacts smoothly with mercaptans to yield N-methylated sulfonamide diimines, the reaction of chloramine with either methyl or dodecyl mercaptan failed to yield an isolable product corresponding to the unsubstituted sulfonamide diimines. Vigorous reactions occurred even at $-80°$, and the reaction product from dodecyl mercaptan showed N–H bands and infrared absorption in the 7–12-μ region reminiscent of the methylchloramine reaction products. However, the products were found to be complex mixtures that contained S and N in *ca.* 1:2 ratio. It seems likely that sulfonamide diimines were formed, but underwent facile condensation reactions to form polymeric species.



The ease with which acid-catalyzed hydrolysis of the N-methyl derivatives occurs is consistent with this idea, and inspection of the above formula reveals that such polymers cannot form (without N-methyl cleavage) when each nitrogen bears an N-methyl substituent.

Experimental Section

Melting points (Mel-Temp apparatus) and boiling points are uncorrected. Physical properties, infrared bands, and analytical data on new compounds are presented in Table IV. Nmr data were presented in Table II.

N-Methylalkanesulfonamide Bis(methylimines). Methylchloramine was generated as previously described[5] using a reactor configuration wherein methylamine was diluted with nitrogen and flow rates of N_2 = 50, Cl_2 = 12, and CH_3NH_2 = 48 mmol/min; this produced 0.56 mol of methylchloramine/hr for up to 2 hr before the glass wool filter had to be replaced. The methylchloramine was trapped in chloroform at Dry Ice temperatures, using 400 ml/mol, and a chloroform solution of the mercaptan (0.3 mol/mol of methylchloramine) was added dropwise at a temperature near 0°. The reaction mixture was allowed to warm overnight to room temperature with stirring and filtered. The filtrate and washings were partially evaporated and refiltered, and the evaporation was finished. The product was taken up in chloroform and washed with 50% potassium carbonate till chloride-free; the solvent was evaporated and the product distilled or recrystallized. The ethanesulfonamide derivative was recrystallized from ethyl acetate or hexane, the butane derivative from pentane at ice temperature, and the dodecane derivative from pentane at Dry Ice temperature.

The dodecyl mercaptan reaction product was first chromatographed on silica gel. Didodecyl disulfide, eluted by hexane, was identified by its infrared spectrum, boiling point (200° (0.2 mm)), and mixture melting point with authentic material. Alcohol eluted the bis(methylimine) which was contaminated with sulfonamide methylimine according to thin layer chromatography and infrared spectra. Repeated chromatography failed to yield pure material; a reasonably pure sample was finally obtained by recrystallization.

Thin layer chromatography (on silica gel G) using a chloroform–tetrahydrofuran–methanol–pyridine (20:40:40:2) solvent mixture furnished a useful criterion of purity. The chromatograms were developed with a ninhydrin spray.

N,N-Dimethylmethanesulfonamide Bis(methylimine). Acetonitrile (1200 ml) was cooled to −40°, and 93.3 g (3.00 mol) of methylamine was added. Chlorine (1.50 mol) was metered into the acetonitrile at −40 to −35° at 12.5 mmol/min. The reaction mixture was then filtered through glass-fiber paper and the positive halogen titrated iodometrically (1.30 mol total). Dimethylamine (135 g, 3.0 mol) was mixed with 50.5 g (0.50 mol) of N,N-dimethylmethanesulfenamide in acetonitrile and added to the methylchloramine at +20°. The reactants were stirred overnight, during which time the positive halogen was consumed. The reaction mixture was concentrated and filtered and the filtrate washed free of chloride with 50% potassium carbonate (filtered to remove precipitated potassium chloride). After evaporating and drying over potassium hydroxide pellets, the product was distilled; yield 15.7 g (21%). A yellowish color and an impurity revealed by a 6.0-μ infrared band

Table IV. Analytical Data and Physical Constants of New Compounds

Compound	Bp, °C (mm)	Mp, °C	% C Calcd	% C Found	% H Calcd	% H Found	% S Calcd	% S Found	% N Calcd	% N Found	Principal ir bands,[d] μ
$CH_3S(NCH_3)_2NHCH_3$	70 (0.1)	18[b]	35.5	35.6[a]	9.7	9.85[a]	31.1	31.2[a]	23.7	23.6[a]	8.3, 8.5, 9.15, 9.4, 10.15, 11.4(s); 3.2, 3.4, 3.55, 6.9, 7.1, 10.4, 12.0 (m); 7.65 (w)
$CH_3S(NCH_3)_2N(CH_3)_2$	52 (0.5)	...	40.2	40.1	10.1	9.8	21.5	21.4	28.1	27.8	8.2–8.5, 9.1, 10.15, 10.55, 10.75, 11.4, 13.65 (s); 3.35, 3.45, 3.52, 6.85, 12.1, 13.35 (m); 7.0, 7.65; 9.55 (w)
$C_2H_5S(NCH_3)_2NHCH_3$	70 (0.1)	61–62.5[c]	40.6	40.2	9.5	9.1	21.6	21.7	28.35	28.4	3.25, 3.4, 3.55, 3.6, 8.3, 8.5, 9.2, 9.35, 9.5, 11.1 (S); 6.9, 7.1 (m); 7.3, 10.2, 12.0, 12.9 (w)
$C_4H_9S(NCH_3)_2NHCH_3$	107 (0.04)	44–45	47.4	(46.1)	10.8	10.8	18.1	18.2	23.7	23.7	3.4, 8.3, 8.5, 9.35, 11.0 (s); 3.25, 3.55, 6.9, (m); 12.2 (w)
$C_{12}H_{25}S(NCH_3)_2NHCH_3$	...	32–33	62.2	61.7	12.2	13.8	11.1	11.2	14.5	13.9	3.4, 3.55, 8.3, 8.5, 9.3, 10.9 (s); 3.25, 3.55, 6.9, 11.3 (m)
$CH_3S(O)(NCH_3)NHCH_3$	60 (0.06)	...	29.7	30.3	8.3	8.4	26.2	26.0	22.9	22.9	8.0, 8.65, 9.1, 9.4, 10.2, 11.65 (s); 3.05, 3.2, 3.4, 5.45, 3.55, 6.9, 7.1, 7.6, 10.4, 12.2–12.8 (m)
$C_4H_9S(O)(NCH_3)NHCH_3$	72 (0.05)	40–41	43.8	43.7	9.8	10.0	19.5	19.4	17.1	16.8	3.4, 8.0, 8.7, 8.8–9.3 (s); 3.0–3.2, 6.9–7.1, 10.9, 11.16, 12.2 (m)
$C_{12}H_{25}S(O)(NCH_3)NHCH_3$	...	43–45	60.8	60.7	11.7	11.8	11.6	11.5	10.1	10.4	3.4, 3.5, 8.0, 8.65 (s); 3.1, 3.2, 3.3, 3.55, 6.9, 9.1, 9.3, 11.4 (m); 7.15 (w)
$CH_3S(O)(NCH_3)N(CH_3)_2$	45 (0.14)	...	35.3	35.5	8.9	8.9	23.5	23.6	20.6	20.2	7.85, 8.55, 10.2, 10.6, 12.8 (s); 3.3, 3.4, 6 8, 7.5, 8.35, 9.0, 11.6 (m); 3.25, 3.5, 7.0, 9.5 (w)

[a] Determined by Spang Microanalytical Laboratories, Ann Arbor, Mich. All other data from our laboratories with special precaution taken to transfer in a dry atmosphere. [b] Picrate, mp 127.5–128° dec. [c] Picrate, mp 117.5–118° dec. [d] Infracord.

could be removed by refluxing 1–2 hr with 2 *N* potassium hydroxide, salting out with potassium carbonate, extracting, and redistilling.

N,N-Dimethylmethanesulfenamide was also treated with methylchloramine as described above for the mercaptans. The major product, isolated in 85% yield, was N-methylmethanesulfonamide bis(methylimine). No bands corresponding to the N,N-dimethyl compound were detected in the infrared spectrum.

Acid Hydrolyses; Preparation of N-Methylalkanesulfonamide Methylimines. Any of the bis(methylimines) were completely hydrolyzed after refluxing 30 min with at least 2 equiv of 2 *N* hydrochloric acid. The products were isolated in *ca.* 80% yields by salting out with potassium carbonate, filtering, extracting, and distilling or crystallizing.

The N,N-dimethylmethanesulfonamide bis(methylimine) (795 mg) was hydrolyzed as above. The hydrolysate was made basic by the addition of 2 *N* potassium hydroxide, and the volatile amine products were distilled from the reaction into water. Titration of the distillate with standardized 2 *N* hydrochloric acid gave 96% of the expected value. The titrated solution was freeze dried and the hydrochloride placed in a flask which was fitted with a septum and an expansion chamber (a 100-ml syringe) and immersed in an 85° bath. Potassium hydroxide (2 ml, 50%) was added using a syringe, and the gaseous amines liberated were analyzed by gas chromatography on a 10% tetraethylenepentamine on 80–100 mesh Porapak Q column (Waters Associates, Inc.) at 73°. Area correction factors were determined from known mixtures of methyl- and dimethylamine. The amines formed in the hydrolysis were comprised of 98 mol % dimethylamine and 2 mol % methylamine.

The infrared spectrum of the sulfonamide methylimine product isolated from the hydrolysis was identical with that of N-methylmethanesulfonamide methylimine produced by hydrolysis of the N-methyl bis(methylimine). Gas chromatographic analysis on a 20% silicone rubber on Chromosorb column at 146° showed only a single peak. Comparison of the chromatograms with those of a mixture of 1% N,N-dimethylmethanesulfonamide methylimine in the N-methyl compound indicated that less than 0.1% of the N,N-dimethyl compound was formed in the hydrolysis. The N,N-dimethyl compound is eluted before the N-methyl compound begins to emerge by 0.5 min, and the two are cleanly separated.

Formation and Alkylation of Sodium Salts of N-Methylalkanesulfonamide Methylimines and Bis(methylimines). Sodium hydride (0.90 g, 37.5 mmol, weighed as a 60% suspension in mineral oil) was placed in a standard 100-ml, three-necked apparatus and washed free of mineral oil with hexane by decantation under argon. Monoglyme (40 ml) (redistilled from hydride) was added, and the apparatus connected to an inverted, water-filled, 1-l. graduate cylinder thru a drying tube. N-Methylmethanesulfonamide methylimine (3.66 g, 30.0 mmol) in 10 ml of monoglyme was added dropwise. Gas evolution was rapid and complete within 10 min. The volume collected corresponded to 103% of theory after correcting to STP. Methyl iodide (4.7 g, 33 mmol) was added; the temperature rose to 47°. After stirring 1 hr, the excess hydride was cautiously decomposed with water, and 50 ml of 50% potassium carbonate was added. The monoglyme layer was evaporated, the residue extracted with benzene, and the product distilled after removing solvent (yield 2.04 g, 50%). Analysis by gas chromatography (141°, silicone rubber–Chromosorb column) revealed only one component and showed that the product contained no starting material.

The above reaction was duplicated with N-methylmethanesul-

fonamide bis(methylimine). The yield of hydrogen was 101%; the yield of product was 78%. The boiling point and infrared spectrum of the product were identical with those of the compound prepared from N,N-dimethylmethanesulfenamide and methylchloramine (above).

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Polylithiation. II.[1] Polylithiation of Toluene and the Formation of Poly(trimethylsilyl)toluenes

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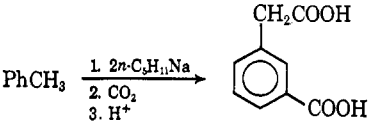
Abstract: Toluene undergoes polylithiation by excess *n*-butyllithium in the presence of N,N,N′,N′-tetramethylethylenediamine. Derivatization of the reaction mixture with trimethylchlorosilane yields α,α,p-tris(trimethylsilyl)toluene as the major product along with mono- and bis(trimethylsilyl)toluenes. α,p- and α,o-dilithiotoluene and α,α,p-trilithiotoluene appear to be the principal polylithiated species produced from toluene. Lithiation experiments were also carried out on benzyltrimethylsilane, *o*-, *m*-, and *p*-trimethylsilyltoluenes, benzyllithium, and *o*-, *m*-, and *p*-lithiotoluenes, producing a series of new bis- and tris(trimethylsilyl)toluenes.

Toluene is known to react with alkylsodium and alkylpotassium compounds to give benzylsodium and benzylpotassium. The dimetallation of toluene by excess *n*-amylsodium has been studied by Morton, who found that homoisophthalic acid was produced when disodiotoluene was derivatized with carbon dioxide.[2]



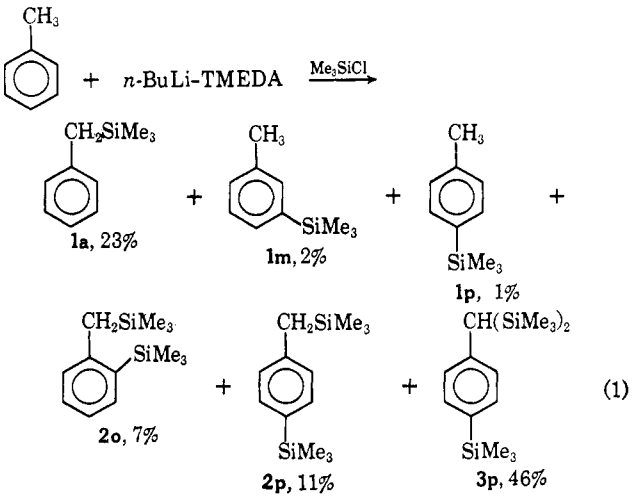
(1)

Metallation of toluene with alkyllithium compounds was generally unsuccessful until the discovery that tertiary amines activate alkyllithium compounds in metallation reactions.[3] Using either diazabicyclo[2.2.2]octane (DABCO) or N,N,N′,N′-tetramethylethylenediamine (TMEDA), Eberhardt and Butte found that toluene undergoes quantitative metallation to benzyllithium with *n*-butyllithium.[4]

In connection with our studies of polylithiation,[1] we have investigated the reaction of toluene with excess *n*-butyllithium in the presence of TMEDA. The addition of toluene to an excess of *n*-BuLi–TMEDA in hexane results in a bright orange solution which gradually turns deep red, separates into two liquid layers, and finally solidifies into a red precipitate and a colorless solution. The lithiated toluene mixture was studied by derivatizing with trimethylchlorosilane and with deuterium oxide. The results indicate that up to three atoms of hydrogen on the toluene nucleus can be replaced by lithium.

(1) R. West, P. A. Carney, and I. C. Mineo, *J. Am. Chem. Soc.*, **87**, 3788 (1965), will be taken as the first paper in this series.
(2) A. A. Morton, E. L. Little, and W. O. Strong, *ibid.*, **65**, 1339 (1943).
(3) H. Gilman, *Org. Reactions*, **8**, 258 (1957).
(4) G. G. Eberhardt and W. A. Butte, *J. Org. Chem.*, **29**, 2928 (1964). The tetra- and pentalithiation of toluene by ethyllithium at 100° has also been reported.[5] However, our attempts to repeat this experiment gave no polylithiation and only a low yield of benzyllithium.
(5) T. V. Talalaeva and K. A. Kocheshkov, *Dokl. Akad. Nauk SSSR*, **77**, 621 (1951).

Derivatization with Trimethylchlorosilane. Treatment of the lithiated toluene with Me_3SiCl produced a mixture of mono-, di-, and trisilylated products, as shown in eq 1. The per cent yields given are only



(1)

illustrative; although the ratios **1a**:**1m**:**1p** and **2o**:**2p** remain essentially constant, the total amounts of mono-, di-, and trisilylated products varied with conditions of the metallation reaction. However, reactions under a wide variety of conditions gave *only the isomers shown* and no others.

The amount of TMEDA used in the reaction was varied over a factor of 200 to establish the optimum N:Li ratio (Table I). Even at very low TMEDA concentration (N:Li = 1:10) a substantial amount of trisubstituted product was produced. However, the highest yield of polymetallated products was obtained with N:Li = 1:2, and this ratio was used in all subsequent experiments.

The influence of the *n*-butyllithium:toluene ratio on the yield of mono-, di-, and trisubstituted products was also studied. The results are given in Table II. Even with equimolar amounts of *n*-butyllithium and