The Reactions of N,N,N′,N′-Tetraalkylsulfurous Diamide–Phenyl Isocyanate Adducts

Teruaki Mukaiyama, Hideo Shimizu, and Hisashi Takei

Laboratory of Organic Chemistry, Tokyo Institute of Technology, Ookayama, Meguro-ku, Tokyo, Japan

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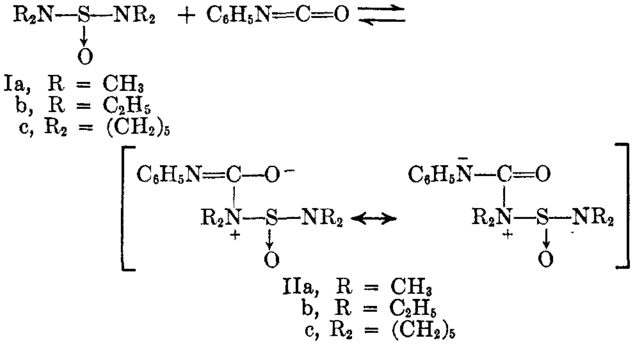
N,N,N′,N′-Tetraalkylsulfurous diamides (I) and phenyl isocyanate gave 1:1 adducts (II). Compounds II react readily with active hydrogen compounds such as alcohols, carboxylic acids, and mercaptans to give N,N-dialkyl-N′-phenylureas, and alkyl dialkylamidosulfites, N,N-dialkylcarboxylic amides, and S-alkyl dialkyalmidothiosulfites, respectively. In a similar manner, I gave 1:1 adducts (IIIa or IIIb) with phenyl isothiocyanate or carbon disulfide. Ethyl dimethylamidosulfite and N,N-dimethyl-N′-phenylthiourea or bis(dimethylthiocarbamoyl) disulfide were obtained by treating IIIa or IIIb with ethanol. Further, the reactions of S-alkyl dimethylamidothiosulfites were studied.

In the preceding paper, the reactions of N,N,N′,N′-tetraalkylsulfurous diamides (I) with alcohols, carboxylic acids, acyl chlorides, carboxylic anhydrides and aldehydes were described.[1]

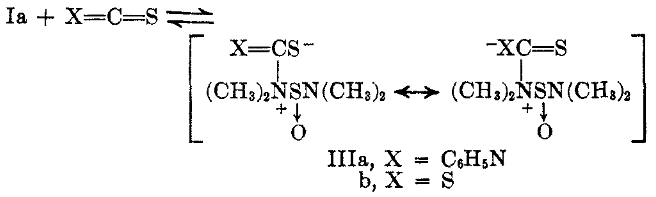
In the present experiment, further study on the reactions of I with phenyl isocyanate, phenyl isothiocyanate, and carbon disulfide were tried. When phenyl isocyanate was added to an ethereal solution of N,N,N′,N′-tetramethylsulfurous diamide (Ia), an exothermic reaction took place soon. Infrared absorption spectrum of a solution of Ia and phenyl isocyanate in Nujol showed that the characteristic band of isocyanate group (2250 cm^{-1}) almost disappeared and a new strong band at 1650 cm^{-1} appeared. Based on this result, it may be noted that Ia reacts with phenyl isocyanate to form 1:1 adduct (IIa), a betaine, shown in the following scheme. This structure is analogous to that of the adduct of triethylamine and phenyl isocyanate.[2]


Ia, R = CH_3
b, R = C_2H_5
c, R_2 = $(CH_2)_5$

IIa, R = CH_3
b, R = C_2H_5
c, R_2 = $(CH_2)_5$

Similarly, N,N,N′,N′-tetraethylsulfurous diamide (Ib) and 1,1′-sulfinylbispiperidine (Ic) react with phenyl isocyanate to form the corresponding 1:1 adducts (IIb and IIc).

It was also found that treatment of Ia with phenyl isothiocyanate or carbon disulfide gave the adducts (IIIa and IIIb).

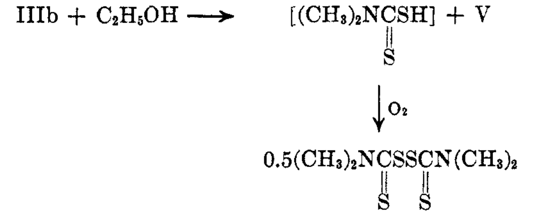

IIIa, X = C_6H_5N
b, X = S

In order to know the behavior of these adducts (II and III), the reaction of the adducts with alcohols was studied. When ethanol was added to an ethereal solution of the adduct, IIa, a vigorous reaction took place soon and N,N-dimethyl-N′-phenylurea (IV) was precipitated immediately. From the filtrate, ethyl dimethylamidosulfite (V) was obtained in a 66% yield.

$$\text{IIa} + C_2H_5OH \longrightarrow \underset{\text{IV}}{(CH_3)_2N\overset{}{\underset{\|}{C}}NHC_6H_5}\;(C{=}O) + \underset{\text{V}}{(CH_3)_2NS(\rightarrow O)OC_2H_5}$$

IV V

Similarly, IIIa reacts readily with ethanol to give N,N-dimethyl-N′-phenylthiourea and V in 95 and 57% yields, respectively. When ethanol was added to a solution of IIIb in petroleum ether (bp 30–60°), bis(dimethylthiocarbamoyl) disulfide and V were obtained in good yields. The formation of the disulfide can be explained by assuming an initial formation of dimethyldithiocarbamic acid, which is then converted into the disulfide by air oxidation.



$$\text{IIIb} + C_2H_5OH \longrightarrow [(CH_3)_2NC({=}S)SH] + \text{V} \xrightarrow{O_2} 0.5(CH_3)_2NC({=}S)SSC({=}S)N(CH_3)_2$$

When phenyl isocyanate adducts (II) were treated with various alcohols, the corresponding esters of dialkylamidosulfurous acid were obtained in good yields along with the corresponding trisubstituted ureas. The results are summarized in Table I.

On the other hand, when IIa was treated with phenol instead of alcohol in the above experiment, phenyl dimethylamidosulfite could not be isolated, though IV was obtained in a quantitative yield.

When IIa was treated with benzoic acid at room temperature, IV and N,N-dimethylbenzamide were obtained in good yields along with the evolution of sulfur dioxide. Similarly, treatment of IIb or IIc with benzoic acid gave the corresponding N,N-disubstituted benzamide and trisubstituted urea.

$$\text{II} + C_6H_5COOH \longrightarrow R_2NCONHC_6H_5 + C_6H_5CONR_2 + SO_2$$

When bromine was added to an ethereal solution of IIa, color of bromine disappeared soon and white crystals were separated. The crystals were identified to be N′-*p*-bromophenyl-N,N-dimethylurea (80%). The urea may be produced by the rearrangement of N′-bromo-N,N-dimethyl-N′-phenylurea initially formed. Treatment of the filtrate with sodium ethoxide gave V in a 67% yield. The V may be pro-

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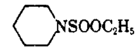
[1] T. Mukaiyama, H. Shimizu, and H. Takei, *Bull. Chem. Soc. Japan*, **40**, 939 (1967).

[2] M. Pestemer, *Angew. Chem.*, **72**, 612 (1960).

TABLE I

PREPARATION OF R_2NSOOR' FROM ADDUCT II AND ALCOHOL

R_2NSOOR'	Yield, %	Bp [lit.], °C (mm)	Calcd, % C	Calcd, % H	Calcd, % N	Found, % C	Found, % H	Found, % N
$(CH_3)_2NSOOC_2H_5$	70	67–68 (20), [61 (13)][a]	35.20	7.99	10.12	35.03	8.09	10.21
$(CH_3)_2NSOOCH_2CH{=}CH_2$	74	84–85 (15)	40.59	7.40	9.20	40.26	7.43	9.39
$(CH_3)_2NSOOcycloC_6H_{11}$	78	88–89 (2.0)	50.25	8.96	7.33	50.14	8.80	7.62
$(CH_3)_2NSOOCH_2C_6H_5$	74	92–93 (0.08)	54.26	6.58	7.03	54.53	6.32	7.29
$(C_2H_5)_2NSOOC_2H_5$	75	80 (11), [80 (10)][b]						
 $NSOOC_2H_5$	67	115–117 (17), [108 (10)][b]						

[a] G. Zinner and W. Kölling, *Naturwissenschaften*, **46**, 354 (1959). [b] G. Zinner, *Chem. Ber.*, **91**, 966 (1958).

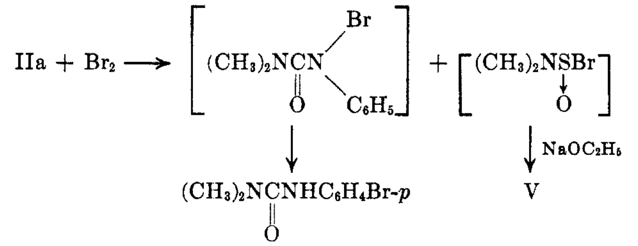
TABLE II

PREPARATION OF $(CH_3)_2NSOSR$ FROM ADDUCT II AND MERCAPTAN OR THIOPHENOL

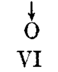
$(CH_3)_2NSO—SR$	Yield, %	Bp, °C (mm)	Calcd, % C	Calcd, % H	Calcd, % N	Found, % C	Found, % H	Found, % N
$R = C_2H_5$	90	80–82 (4)	31.37	7.24	9.15	31.30	7.14	9.12
$R = n\text{-}C_3H_7$[b]	84	89–91 (4)	35.93	7.78	8.38	36.22	7.89	8.48
$R = n\text{-}C_4H_9$[c]	75	80–81 (0.4)	39.77	8.34	7.73	40.29	8.45	7.68
$R = C_6H_5CH_2$	...	Liquid[a]						
$R = C_6H_5$	...	Liquid[a]						

[a] This was not obtained in analytical purity, but the structure was confirmed by its infrared spectrum. Attempts to purify this liquid further by distillation resulted in decomposition. [b] Registry no. 14181-69-2. [c] Registry no. 14181-70-5.

duced by the condensation of dimethylamidosulfurous bromide with sodium ethoxide.



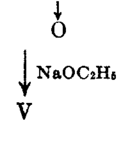
Finally, the reaction of II with mercaptans was tried. When ethylmercaptan was added to a benzene solution of IIa, an exothemic reaction took place soon and IV was separated immediately. From the filtrate, S-ethyl dimethylamidothiosulfite (VIa) was obtained in a 90% yield. The VIa was identified by its elemental analyses and its infrared absorption spectrum which shows characteristic bands of sulfinyl group (1125 cm^{-1}) and sulfur–nitrogen linkage (924 cm^{-1}). The results of the reactions of II with mercaptans and thiophenol are listed in Table II.



$$II + R'SH \longrightarrow IV + R_2N\underset{\substack{\downarrow\\ O}}{S}SR'$$

VI

When VIa was treated with mercuric chloride in tetrahydrofuran at room temperature, ethylmercapto mercuric chloride was separated soon. By the treatment of the filtrate with sodium ethoxide, V was obtained in a 60% yield. This result suggests an initial formation of dimethylamidosulfurous chloride which in turn condenses with sodium ethoxide to yield V.



$$VIa + HgCl_2 \longrightarrow C_2H_5SHgCl + [(CH_3)_2N\underset{\substack{\downarrow\\ O}}{S}Cl] \xrightarrow{NaOC_2H_5} V$$

When a solution of lead tetraacetate in dry benzene was added to a solution of S-phenyl dimethylamidothiosulfite (VIb), lead acetate precipitated immediately. After removal of the solvent, diphenyl disulfide was obtained in a 70% yield along with N,N-dimethylacetamide (75%). Similarly, dibenzyl disulfide and N,N-dimethylacetamide were obtained in 89 and 81% yields, respectively, when S-benzyl dimethylamidothiosulfite (VIc) was treated with lead tetraacetate. The reaction of VIb with dibenzoyl peroxide in refluxing benzene gave diphenyl disulfide (75%) and N,N-dimethylbenzamide (80%) as shown below.

$$2VI + Pb(OCOCH_3)_4 \longrightarrow Pb(OCOCH_3)_2 + RSSR + 2CH_3CON(CH_3)_2 + 2SO_2$$

$$R = C_6H_5 \text{ or } C_6H_5CH_2$$

$$2VIb + (C_6H_5COO)_2 \longrightarrow C_6H_5SSC_6H_5 + 2C_6H_5CON(CH_3)_2 + 2SO_2$$

Experimental Section

All melting points and boiling points are uncorrected. N,N,-N',N'-Tetraalkylsulfurous diamide were prepared according to the direction of A. Michaelis.[3]

Reaction of N,N,N',N'-Tetramethylsulfurous Diamide–Phenyl Isocyanate Adduct (IIa) with Ethanol.—To a solution of N,N,N',N'-tetramethylsulfurous diamide (Ia) (1.36 g, 10 mmoles) in 5 ml of dry ether cooled in an ice bath, phenyl isocyanate (1.19 g, 10 mmoles) in 10 ml of dry ether was added dropwise with stirring. The mixture was kept standing at room temperature for 1 hr, and then a solution of ethanol (0.46 g, 10 mmoles) in 5 ml of ether was added. An exothermic reaction took place and N,N-dimethyl-N'-phenylurea (IV) was precipitated immediately. Compound IV was collected and recrystallized from water: yield 1.6 g (quantitatively), mp 134° undepressed on admixture with an authentic sample. After removal of the solvent, the filtrate was distilled under reduced pressure to yield 0.9 g (66%) of ethyl dimethylamidosulfite (V), bp 67–68° (20 mm).

Similarly, allyl, cyclohexyl, and benzyl dimethylamidosulfites were prepared from IIa and corresponding alcohols. Ethyl diethylamidosulfite and ethyl 1-piperidinesulfinate were also obtained by the reaction of adducts (IIb and IIc) with ethanol. The results are listed in Table I.

Reaction of N,N,N',N'-Tetramethylsulfurous Diamide–Phenyl Isothiocyanate Adduct (IIIa) with Ethanol.—A solution of phenyl isothiocyanate (1.35 g, 10 mmoles) in dry ether was added dropwise to an ice-cooled solution of Ia (1.36 g) in the

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(3) A. Michaelis, *Chem. Ber.*, **28**, 1015 (1895).

same solvent. The mixture was kept standing at room temperature for 1 hr, and then a solution of ethanol (0.46 g) in dry ether was added. The precipitate of N,N-dimethyl-N′-phenylthiourea (1.70 g, 95%) was removed and the filtrate was concentrated under reduced pressure. The residue was distilled to give 0.8 g of V, bp 64–67° (16 mm).

Reaction of N,N,N′,N′-Tetramethylsulfurous Diamide–Carbon Disulfide Adduct (IIIa) with Ethanol.—A solution of carbon disulfide (0.76 g, 10 mmoles) in petroleum ether was added to a solution of Ia (1.36 g) in the same solvent. The mixture was kept standing at room temperature for 0.5 hr, and then a solution of ethanol (0.46 g) in petroleum ether was added. The precipitate was collected, washed, and recrystallized from chloroform–ethanol to give 2.0 g (83%) of bis(dimethylthiocarbamoyl) disulfide, mp 146–148°. The filtrate was concentrated and distilled to give V in a 54% yield (0.7 g).

Reaction of IIa with Benzoic Acid.—The procedure used here was virtually identical with that described for the reaction of IIa with ethanol. The precipitate of IV was removed and the filtrate was concentrated under vacuum. The residual liquid was distilled to give 0.89 g (60%) of N,N-dimethylbenzamide, bp 100–103° (3 mm).

Similarly, N,N-diethylbenzamide and benzpiperidide were obtained from corresponding adducts (IIb and IIc) and benzoic acid. N,N-Diethylbenzamide (53%) had bp 132–134° (2 mm) and benzpiperidide (93%), mp 47–49°.

Reaction of IIa with Bromine.—A solution of bromine (1.60 g, 10 mmoles) in dry carbon tetrachloride was added dropwise to an ice-cooled ethereal solution of IIa which was prepared from Ia (1.36 g) and phenyl isocyanate. Color of bromine disappeared soon and colorless crystals began to precipitate. The precipitate of N′-*p*-bromophenyl-N,N-dimethylurea was collected and recrystallized from ethanol: yield 2.0 g (80%), mp 169°.

Anal. Calcd for $C_9H_{11}BrN_2O$: C, 44.46; H, 4.76; N, 11.52. Found: C, 44.39; H, 4.56; N, 11.53.

A solution of equimolecular amount of sodium ethoxide in ethanol was added to the filtrate. After removal of the precipitated sodium bromide by a centrifugal separation and of the solvent under reduced pressure, the residual liquid was distilled to give ethyl dimethylamidosulfite (V) (0.9 g, 67%), bp 67–68° (20 mm).

Reaction of IIa with Ethyl Mercaptan.—This reaction was carried out in a nitrogen atmosphere. An ethereal solution of ethyl mercaptan (0.62 g, 10 mmoles) was added to an ice-cooled ethereal solution of IIa which was prepared from Ia (1.36 g) and phenyl isocyanate (1.19 g). The precipitated IV was removed by filtration and the filtrate was concentrated under reduced pressure. The residual liquid was distilled to give 1.37 g (90%) of S-ethyl dimethylamidothiosulfite (VIa), bp 80–82° (4 mm).

Similarly S-*n*-propyl, S-*n*-butyl, S-benzyl, and S-phenyl esters of dimethylamidothiosulfurous acid were obtained from IIa and corresponding mercaptans or thiophenol. The results are listed in Table II.

Reaction of S-Ethyl Dimethylamidothiosulfite (VIa) with Mercuric Chloride.—To a solution of VIa (1.53 g) in dry tetrahydrofuran, a solution of mercuric chloride (2.7 g) in the same solvent was added dropwise with vigorous stirring. Ethylmercapto mercuric chloride precipitated immediately. This (1.8 g, 80%) was removed by filtration and then a solution of equimolecular amount of sodium ethoxide in ethanol was added to the filtrate. After removal of the precipitated sodium chloride by centrifugal separation and of the solvent under reduced pressure, the residual liquid was distilled to give 0.8 g (60%) of V.

Reaction of S-Phenyl Dimethylamidothiosulfite (VIb) with Lead Tetraacetate.—A mixture of Ia (2.72 g, 20 mmoles) and phenyl isocyanate (2.38 g, 20 mmoles) in dry benzene was allowed to stand for 1 hr at room temperature, and then a solution of thiophenol (2.20 g, 20 mmoles) in dry benzene was added under nitrogen to the mixture. After removal of the precipitated IV by filtration, a solution of lead tetraacetate (4.4 g, 10 mmoles) in dry benzene was added to the filtrate. Lead acetate precipitated immediately and was removed by filtration (2.2 g, 67%). The filtrate was distilled under reduced pressure to give 1.20 g (70%) of N,N-dimethylacetamide, bp 62–65° (11 mm). The residue crystallized on cooling. This was collected, and then recrystallized from ethanol to give 1.4 g (65%) of diphenyl disulfide (mp 61–62° undepressed on admixture with an authentic sample).

Similarly, the reaction of lead tetraacetate (4.4 g, 10 mmoles) with S-benzyl dimethylamidothiosulfite (VIc) which was obtained from Ia (2.72 g, 20 mmoles), phenyl isocyanate (2.38 g), and benzyl mercaptan (2.50 g, 20 mmoles), gave lead acetate (3.1 g, 100%), N,N-dimethylacetamide (1.4 g, 81%), and dibenzyl disulfide (2.2 g, 89%), mp 70–71°.

Reaction of VIb with Benzoyl Peroxide.—To a solution of 20 mmoles of IIa in dry benzene, a solution of 20 mmoles of thiophenol was added under nitrogen. The precipitated IV was removed by filtration, and then benzoyl peroxide (2.42 g, 10 mmoles) was added to the filtrate. The mixture was refluxed for 1 hr. After removal of the solvent under reduced pressure, the residual liquid was distilled to give 2.4 g (80%) of N,N-dimethylbenzamide, bp 85–87° (0.05 mm). Diphenyl disulfide was obtained from the residue and was recrystallized from ethanol: yield 1.65 g (75%), mp 61–62°.

Registry No.—IIa ($-N{=}C(-O^-)-$), 14182-06-0; IIa ($-N^-{-}C({=}O)-$), 14182-46-8; IIb ($-N{=}C(-O^-)-$), 14182-07-1; IIb ($-N^-{-}C({=}O)-$), 14182-47-9; IIc ($-N{=}C(-O^-)-$), 14182-08-2; IIc ($-N^-{-}C({=}O)-$), 14182-48-0; IIIa ($X{=}C(-S^-)-$), 14182-09-3; IIIa ($X^-{-}C({=}S)-$), 14182-49-1; IIIb ($X^-{-}C({=}S)-$), 14182-10-6; IV, 101-42-8; V, 14181-62-5; VIa, 14271-16-0; VIb, 14181-63-6; VIc, 14181-64-7; $(CH_3)_2NSOOCH_2CH{=}CH_2$, 14181-65-8; $(CH_3)_2NSOO\text{-}c\text{-}C_6H_{11}$, 14181-66-9; $(CH_3)_2NSOOCH_2C_6H_5$, 14181-67-0; N,N-dimethylbenzamide, 611-74-5; N,N-diethylbenzamide, 1696-17-9; benzpiperidide, 776-75-0; N′-*p*-bromophenyl-N,N-dimethylurea, 3408-97-7; dibenzyl disulfide, 150-60-7; diphenyl disulfide, 882-33-7; bis(dimethylthiocarbamoyl) disulfide, 137-26-8.