was induced. The crude mixture of diastereomers was separated by the triangle scheme resulting in 10.4 g of **10** (mp 129.2–129.8°) and 8 g of **11** (mp 106.3–106.9°).

Anal. Calcd for $C_{14}H_{14}O_2S$: C, 68.27; H, 5.73. Found: C, 68.10; H, 5.55.

Anal. Calcd for $C_{14}H_{14}O_2S$: C, 68.27; H, 5.73. Found: C, 68.30; H, 5.72.

Compound **12** was prepared by generation of the lithium salt of phenyl benzyl sulfoxide and addition of this to isobutyraldehyde. Phenyllithium was prepared by adding 7.1 g of bromobenzene (0.046 mol) to 0.65 g of lithium stirred under nitrogen in 50 ml of ether. To this was added phenyl benzyl sulfoxide (9.0 g, 0.046 mol) dissolved in a minimum amount of tetrahydrofuran. To the resulting orange solution, isobutyraldehyde was added until the color was eliminated. The product was stirred 10 min and then added to NH_4Cl on ice. The product was taken up in warm chloroform (*ca.* 100 ml) and extracted twice with water and dried ($MgSO_4$). Separation by crystallization by the triangle scheme afforded some of two sulfoxides, mp 177–178° and 122–123°, and starting material, mp 125–126°. After a few cycles no more pure sulfoxides could be obtained. The remaining solutions were combined, concentrated, and chromatographed on a 2 × 26 cm column of Florisil.

The low-melting sulfoxide was eluted with 50% benzene in hexane yielding a total of 2.7 g from all sources. Then starting material was eluted (total of 0.9 g). Finally a mixture of sulfoxides and starting material was eluted with *ca.* 20% ether in benzene. From this more of the high-melting sulfoxide was obtained, mp 177–178° (2.2-g total). The remainder, 0.3 g, was a mixture of the high-melting sulfoxide and another sulfoxide which could not be further purified. Compound **12** melted at 122.5–123.5°.

Anal. Calcd for $C_{17}H_{20}O_2S$: C, 70.80; H, 6.94. Found: C, 70.38; H, 7.12.

The nmr spectra were determined on a Varian A-60D instrument. The coupling constants were determined from the average of several traces of expanded spectra. In order to observe hydroxyl splittings, the chloroform solvent had to be purified by distillation from barium oxide and used soon after distillation. It was belatedly found that Linde Molecular Seive 4A would keep the solvent free from hydrochloric acid. The ABX spectra of **10** and **11** were simulated using computer techniques until the calculated trace of the spectrum was superimposible on the original. The solvent DMSO was redistilled from molecular sieve. The ir spectra were determined on a Perkin-Elmer 237 instrument standardized *vs.* polystyrene. The absorptions quoted are considered reliable to ±5 cm^{-1}. The molecular weights were determined on a Hewlett-Packard osmometer standardized *vs.* benzil, using ethanol-free chloroform as solvent. The low concentration molecular weights were determined by Dornis and Kolbe, Mülheim, West Germany. Within the context of this work, a "free" hydroxyl infrared absorption is intended to signify a hydroxyl not bonded to sulfoxide. In the ir spectra, a weak absorption at 3700 cm^{-1} was noted which was considered spurious.

Registry No.—**2**, 28520-72-1; **2** OBz, 28520-73-2; **3**, 28455-72-3; **3** OBz, 28455-73-4; **4**, 28455-74-5; **5**, 28455-94-9; **6**, 28455-75-6; **6** OBz, 28455-76-7; **7a** OBz, 28455-76-7; **7b**, 28455-78-9; **8**, 28520-74-3; **8** OBz, 28455-79-0; **9**, 28520-75-4; **10**, 28455-80-3; **11**, 28520-76-5; **12**, 28455-81-4.

Reactions of Carbanions of Dimethyl Sulfoxide and Dimethyl Sulfone with Isocyanates, Isothiocyanates, and Other Electrophilic Reagents. Preparation of β-Amido and β-Thioamido Sulfoxides and Sulfones

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Reaction of the carbanions of dimethyl sulfoxide and dimethyl sulfone with isothiocyanates gave β-thioamido sulfoxides and β-thioamido sulfones, respectively (Table I, C and E). With isocyanates, the anion of dimethyl sulfone yields methylsulfonylmalonamides (D), whereas the anion of dimethyl sulfoxide gives a mixture of β-amido sulfoxides and methylsulfinylmalonamides (A and B).

Additions of the conjugate bases of dimethyl sulfoxide or dimethyl sulfone to esters,[1,2] Schiff bases,[1] aldehydes, and ketones[3] have led to the preparation of a variety of substituted sulfoxides and sulfones. In view of the proven usefulness of these compounds in organic synthesis,[4] and of our continuing interest in new carbon to carbon bond formations,[5] we have investigated the reaction of the carbanions of dimethyl sulfoxide and dimethyl sulfone with other electrophilic reagents, such as isocyanates, isothiocyanates, nitrile, isonitrile, and benzoxazinone.

Addition of phenyl isocyanate to a solution of sodium methylsulfinylmethide gave two readily separable compounds which were assigned structures **1** and **2** (Scheme I).

The structure assignment of compound **2** was based on elemental analysis and the following physical data: ν^{Nujol} 3280 (NH), 1680 (CO), 1040 cm^{-1} (SO); $\lambda_{\mathrm{max}}^{\mathrm{EtOH}}$ 253 mμ (ε 25,400) (nearly twice as intense as the corresponding band of **1**); δ (DMSO) singlet at 4.91 (CH), two one-proton singlets in the $CONHC_6H_5$ region (confirmed by D_2O exchange) at 9.43 and 9.69 ppm. Compound **2** was readily cleaved to malonanilide in aqueous base. Compound **1** has been previously described;[6] spectral evidence supporting its structure is given in the Experimental Section.

Attempts at directing the synthesis toward exclusive formation of **2** by the use of a large excess of isocyanate resulted in lower yields of **2**. In line with this finding was the observation that the anion of **1** was converted to **2** very slowly, even in the presence of a large excess of isocyanate. This is perhaps surprising, since step **1** → **2** appears to be irreversible, as indicated by the failure to produce some **1** by treatment of **2** with sodium hydride.

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[1] E. J. Corey and M. Chaykovsky, *J. Amer. Chem. Soc.*, **87**, 1345 (1965).

[2] (a) H. D. Becker and G. A. Russell, *J. Org. Chem.*, **28**, 1896 (1963); (b) H. O. House and J. K. Larson, *ibid.*, **33**, 61 (1968).

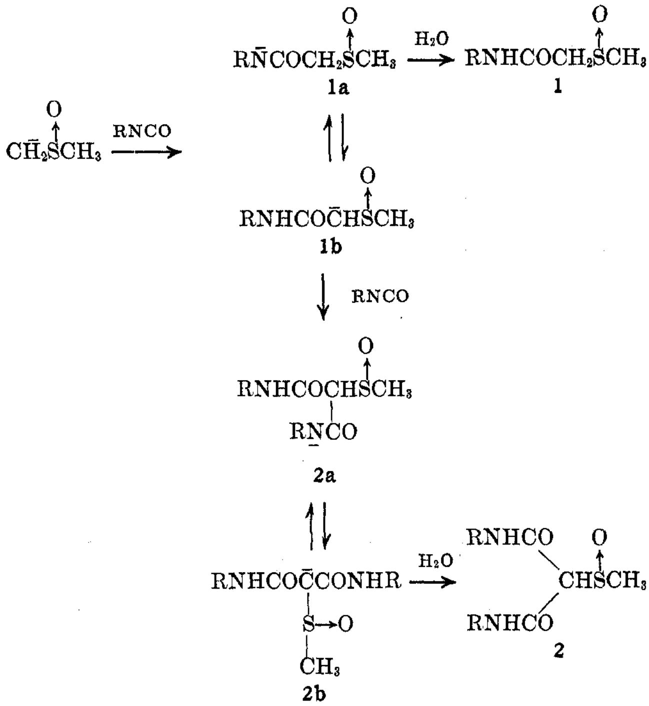
[3] (a) E. J. Corey and M. Chaykovsky, *J. Amer. Chem. Soc.*, **84**, 866 (1962); (b) G. A. Russell and H. D. Becker, *ibid.*, **85**, 3406 (1963).

[4] G. A. Russell and L. A. Ochrymowycz *J. Org. Chem.*, **34**, 3618 (1969).

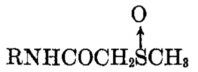
[5] (a) M. von Strandtmann, M. P. Cohen, C. Puchalski, and J. Shavel, Jr., *ibid.*, **33**, 4306 (1968); (b) M. von Strandtmann, M. P. Cohen, and J. Shavel, Jr., *Tetrahedron Lett.*, **35**, 3103 (1965).

[6] N. Hellstrom and T. Lauritzson, *Ber.*, **69**, 1999 (1936).

SCHEME I

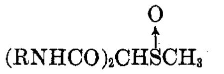


Several other isocyanates employed in this reaction behaved analogously. The products are listed in Table I (types A and B).



$\mathrm{RNHCOCH_2\overset{O}{\overset{\uparrow}{S}}CH_3}$

A

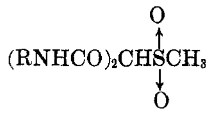


$\mathrm{(RNHCO)_2CH\overset{O}{\overset{\uparrow}{S}}CH_3}$

B

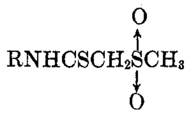
$\mathrm{RNHCSCH_2\overset{O}{\overset{\uparrow}{S}}CH_3}$

C



$\mathrm{(RNHCO)_2CH\overset{O}{\overset{\uparrow}{\underset{\underset{O}{\downarrow}}{S}}}CH_3}$

D



$\mathrm{RNHCSCH_2\overset{O}{\overset{\uparrow}{\underset{\underset{O}{\downarrow}}{S}}}CH_3}$

E

TABLE I[a]

COMPOUNDS PREPARED BY REACTIONS OF DIMETHYL SULFOXIDE OR DIMETHYL SULFONE ANIONS WITH ISOCYANATES AND ISOTHIOCYANATES

Compd	Type	R	Mp, °C	Yield, %
1	A	Phenyl	143–145	10
2	B	Phenyl	170–172	21
3	C	Phenyl	113–114	12.5
4	D	Phenyl	230–231	49
5	A	1-Naphthyl	119–121	19
6	B	1-Naphthyl	197–200	42
7	A	2-Biphenyl	97–99	17
8	B	2-Biphenyl	198–200	37
9	C	2-Naphthyl	104–105	28
10	C	Cyclohexyl	92–93	21
11	C	1-Adamantyl	165–166	59
12	E	1-Adamantyl	175–176	41

[a] Satisfactory analytical values (±0.3% for C, H, N, and S) were reported for all compounds in the table: Ed.

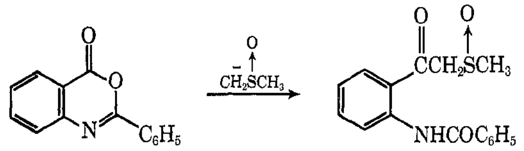
In the case of isothiocyanates the sole isolable products were the β-thioamido sulfoxides (Table I, type C). Apparently, because of the lesser electronegativity of sulfur as compared to oxygen, the methylene group of the primary product is insufficiently acidic to undergo reaction with a second mole of the isothiocyanate.

The opposite effect was observed during the reaction of phenyl isocyanate with the anion of dimethyl sulfone. In contrast to the corresponding sulfoxide, the sulfone gave only the product of double addition, β-diamido sulfone **4** (Table I, type D). In this case, the stronger electron-withdrawing effect of the sulfone group probably shifted the equilibrium extensively toward the side of the carbanion.

Compounds of Table I represent a chemical class hitherto virtually unexplored. We were able to find only one pertinent literature reference,[6] namely the preparation of compound **1** by N-acylation of aniline with thioglycolic acid followed by *S*-methylation and oxidation of the resulting *S*-methylthioglycolic anilide to the corresponding sulfoxide.

Our attempts to prepare a β-oximino sulfoxide and a β-imino sulfoxide by addition of sodium methylsulfinylmethide to 2,4,6-trimethylbenzonitrile oxide and to benzonitrile, respectively, were unsuccessful. In the case of benzonitrile, only a low yield of the corresponding β-keto sulfoxide was obtainable in crystalline form,[7] whereas the reaction with the nitrile oxide gave no isolable products under the standard conditions used in this case.

Addition of sodium methylsulfinylmethide to 2-phenyl-4-benz[4]oxazinone produced the expected 2′-[(methylsulfinyl)acetyl]benzanilide (**13**), which may be regarded as the vinylogous form of a β-amido sulfoxide.



13

Experimental Section[8]

I. Preparative Section. Reaction of Sodium Methylsulfinylmethide with 2-Biphenyl Isocyanate.—A mixture of 240 ml of dimethyl sulfoxide, 450 ml of benzene, and 16.5 g (0.4 mol) of 58.6% sodium hydride mineral oil dispersion was heated with stirring under nitrogen for 1 hr at 75–80°. The resulting solution was cooled to 5° and treated dropwise with a solution of 29.3 g (0.15 mol) of 2-biphenyl isocyanate in 250 ml of benzene. The addition was carried out over a period of 0.5 hr, with stirring, and ice-bath cooling to 5°. After the deep yellow solution was allowed to warm to 15–20°, 2 l. of ether was added resulting in a viscous precipitate. After decantation, trituration with ether, and decantation, *ca.* 1.5 l. of cold water followed by 0.5 l. of ether were added and the mixture was stirred vigorously. The aqueous phase was separated and acidified with 35 ml of glacial acetic acid. The separated solid was filtered and washed with *ca.* 200 ml of water and dried to give 13.0 g (37%) of *N,N′*-bis(2-biphenylyl)-2-(methylsulfinyl)malonamide (**8**).

The aqueous filtrate was saturated with sodium chloride and extracted with two 0.5-l. portions of ethyl acetate. The combined extracts were dried over $MgSO_4$, treated with charcoal, filtered, and evaporated under reduced pressure. The residue crystallized upon trituration with ether. It was filtered and washed with ether to give 7 g (17%) of 2-(methylsulfinyl)-2′-phenylacetanilide (**7**). All other compounds of type A and B (**1**, **2**, **5**, and **6**) were prepared by the same method. The analytical samples were obtained by recrystallization from ethyl acetate.

Reaction of Sodium Methylsulfinylmethide with Cyclohexyl Isothiocyanate.—A mixture of dimethyl sulfoxide (100 ml),

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[7] After completion of of studies, G. A. Russell and L. A. Ochrymowycz (ref 4) described the preparation of β-keto sulfoxides from dimethyl sulfoxide and nitriles.

[8] Melting points were determined with the Thomas-Hoover capillary melting point apparatus which was calibrated against known standards. The authors are indebted to Dr. C. Greenough for spectral data and to Mrs. U. Zeek for elemental analyses.

benzene (300 ml), and 57% sodium hydride mineral oil dispersion (14 g, 0.33 mol) was heated at 75–80° with stirring under nitrogen until all the solid had dissolved to give a green solution (1–2 hr). Cyclohexyl isothiocyanate (21.3 g, 0.15 mol) was added over 5 min to the ice-cold solution of the dimethyl sulfoxide anion with vigorous stirring. The reaction mixture was stirred at 40° for 2 hr and poured into a large excess of ether. The white insoluble sodium salts were filtered, washed with ether, and decomposed by the addition of ice. The resulting aqueous solution was extracted with ethyl acetate. The ethyl acetate extracts were dried over sodium sulfate and evaporated to give a brown gum. The gum was triturated several times with petroleum ether (bp 30–60°) and crystallized from ethyl acetate–petroleum ether. Recrystallization from ethyl acetate gave 6.53 g (21%) of ***N*-cyclohexyl-2-(methylsulfinyl)thioacetamide (10)**. The other compounds of type C (**3**, **9**, and **11**) were prepared by the same method.

Reaction of Sodium Methylsulfonylmethide with 1-Adamantyl Isothiocyanate.—A mixture of dimethyl sulfoxide (10 ml), 1,2-dimethoxyethane (50 ml), 57% sodium hydride mineral oil dispersion (4.2 g, 0.1 mol), and dimethyl sulfone (9.4 g, 0.1 mol) was heated at 92–95° with stirring under nitrogen for 2 hr. 1-Adamantyl isothiocyanate (10 g, 0.052 mol) in 1,2-dimethoxyethane (30 ml) was added in 2 min to the ice-cold solution of the dimethyl sulfone anion with vigorous stirring. The reaction mixture was stirred at 35° for 90 min, cooled, and poured onto ice. The white precipitate was filtered and washed with water. Two recrystallizations from methanol gave 5.96 g (41%) of pure ***N*-(1-adamantyl)-2-(methylsulfonyl)thioacetamide (12)**.

Reaction of Sodium Methylsulfonylmethide with Phenyl Isocyanate.—A mixture of dimethyl sulfoxide (40 ml), 1,2-dimethoxyethane (200 ml), 57% sodium hydride mineral oil dispersion (16.5 g, 0.4 mol), and dimethyl sulfone (37.6 g, 0.4 mol) was heated at 80–90° with stirring under nitrogen for 3 hr. Phenyl isocyanate (24 g, 0.1 mol) in 1,2-dimethoxyethane (30 ml) was added in 2 min at 5°. The reaction mixture was stirred at 30–40° for 2 hr, cooled, and poured onto ice. The precipitate was filtered, washed with water, and dried to give *sym*-diphenylurea, 4.5 g (21%).

The aqueous filtrate was acidified with acetic acid. The white precipitate which formed was filtered, washed with water, and dried to give 16.2 g (49%) of **2-(methylsulfonyl)-*N*,*N*′-diphenylmalonamide (4)**. Recrystallization from ethanol gave an analytical sample.

Reaction of Sodium Methylsulfinylmethide with 2-Phenyl-4-oxazinone.—A mixture of dimethyl sulfoxide (25 ml), benzene (45 ml), and 57% sodium hydride mineral oil dispersion (2.5 g, 0.204 mol) was heated at 75–80° with stirring under nitrogen until all the solid had dissolved to give a green solution. 2-Phenyl-4-oxazinone (4.74 g, 0.068 mol) was added to the ice-cold solution of the dimethyl sulfoxide anion with vigorous stirring. The reaction mixture was stirred at 40° for 1 hr and poured into a large excess of ether. The yellow insoluble sodium salts were filtered, washed with ether, and dissolved in water. Acidification with acetic acid gave a white crystalline solid. Further material was obtained by extraction with ethyl acetate. Recrystallization from ethyl acetate gave pure **2-[(methylsulfinyl)acetyl]benzanilide** as white crystals, mp 148–149°, yield 4.08 g (67%). *Anal.* Calcd for $C_{16}H_{15}NO_3S$: C, 63.77; H, 5.02; N, 4.65; S, 10.64. Found: C, 63.66; H, 5.04; N, 4.44; S, 10.88.

II. Structural and Mechanistic Studies. Reaction of Sodium Methylsulfinylmethide with Phenyl Isocyanate (Large Excess).—To the solution of 25 ml of dimethyl sulfoxide in 45 ml of benzene, 1.78 g (0.04 mol) of sodium hydride were added and the mixture was heated for 1 hr at 75°. The resulting solution was cooled to 5° and treated dropwise with a solution of 14.28 g of phenyl isocyanate in 10 ml of benzene. The reaction mixture was allowed to warm to room temperature and was worked up according to the above-described general procedure (compounds **7** and **8**). While none of **1** was detected, the yield of **2** was only 0.5 g (3.8%).

Conversion of 1 to 2.—A solution of 100 mg (0.0005 mol) of **1** in 20 ml of dimethoxyethane was treated with 24 mg (0.001 mol) of NaH and, after 2 hr of stirring, with 119 mg (0.001 mol) of phenyl isocyanate. After 60 hr of stirring at room temperature, traces of **1** were still detectable by tlc (silica gel G, ethyl acetate).

Attempt at Conversion of 2 to 1.—To the solution of 70 mg (0.0002 mol) of **2** in 5 ml of dimethoxyethane, 9.6 mg (0.0004 mole) of sodium hydride were added. After 24 hr at room temperature, tlc failed to reveal presence of **1** in the reaction mixture.

Base Cleavage of 2 to Malonanilide.—A solution of 0.8 g (0.00253 mol) of 2-(methylsulfinyl)-*N*,*N*′-diphenylmalonamide in 20 ml of 1 *N* sodium hydroxide was heated on the steam bath for 1 hr. The separated crystals were filtered, washed well with water, and dried, wt 0.5 g (77.8%), mp 225–227° (lit.[9] 225°). Recrystallization from ethyl acetate gave pure white crystals melting at 227–229°.

Anal. Calcd for $C_{15}H_{14}N_2O_2$: C, 70.85; H, 5.55; N, 11.02. Found: C, 70.98; H, 5.62; N, 10.89.

Spectral Data of 1: ν^{Nujol} 3100–3300 (NH), 1675 (CO), 1015 cm^{-1} (SO); $\lambda_{\text{max}}^{\text{EtOH}}$ 245 mμ (ϵ 14,250) [$\lambda_{\text{max}}^{\text{EtOH}}$ for acetanilide is 242 mμ (ϵ 14,400)[10]]; δ (DMSO) 2.68 (CH_3), 3.81 (CH_2, quartet), 9.90 ppm (NH); mp 143–145° (lit.[6] 136–137°).

Registry No.—**1**, 29124-26-3; **2**, 29124-27-4; **3**, 29124-28-5; **4**, 29124-29-6; **5**, 29124-30-9; **6**, 29124-31-0; **7**, 29124-32-1; **8**, 29124-33-2; **9**, 29124-34-3; **10**, 29124-35-4; **11**, 29124-36-5; **12**, 29124-37-6; dimethyl sulfoxide carbanion, 13810-16-7; dimethyl sulfone carbanion, 29119-74-2; 2-[(methylsulfinyl)acetyl]benzanilide, 29124-38-7.

(9) W. Whiteley, *J. Chem. Soc.*, **83**, 34 (1903).

(10) H. E. Ungnade and R. W. Lamb, *J. Amer. Chem. Soc.*, **74**, 3789 (1954).