130. o-*Mercapto-azo-compounds. Part X.* Reactions of Azobenzene-2-sulphenyl Bromide and its Derivatives with Malonic Acid, Acetone, and Acetophenone.*

By A. Burawoy and A. Chaudhuri.

Azobenzene-2-sulphenyl bromide and its 2-nitro-, 4-nitro-, and 2-benzylthio-derivatives condense with malonic acid, acetone, or acetophenone to yield, in controlled conditions, the corresponding (2-arylazophenylthio)acetic acids (III), acetonyl 2-arylazophenyl sulphides (IV), and 2-arylazophenyl phenacyl sulphides (V), respectively. The tendency of these products to decompose in presence of acid to the corresponding arylamines and benzothiazole-2-carboxylic acid (VI), 2-benzothiazolyl methyl ketone (VII), and 2-benzothiazolyl phenyl ketone (VIII) respectively, offering a novel route for the preparation of benzothiazole derivatives, is discussed.

Sulphenyl chlorides and thiocyanates are known to condense with acetone, acetophenone, or ethyl acetoacetate to form the corresponding sulphides (I).[1] On the other hand, no similar reactions with sulphenyl bromides have been reported. Anthraquinone-1-sulphenyl bromide (like its chloride) does not react with the above-mentioned ketones,[2] whereas 3-nitrotoluene-4-sulphenyl bromide with acetone [3] and 2-nitrobenzenesulphenyl bromide with acetophenone [4] yield acetonyl bromide and phenacyl bromide respectively, in addition to the corresponding disulphides. Similarly, fluorenone-1-sulphenyl bromide, when heated with acetone, is converted into the disulphide, condensation not being observed.[5]

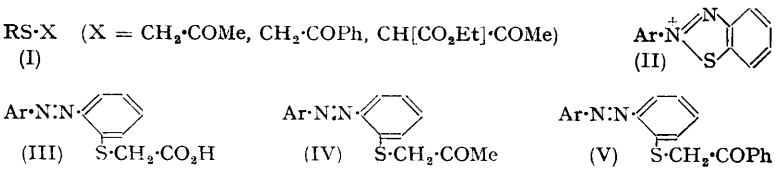
The water-solubility and exceptional stability to heat and hydrolysis of azobenzene-2-sulphenyl bromide and its derivatives, which is mainly due to their ability to exist as true salts involving 2-arylbenzo-1-thia-2 : 3-diazolium ions (II),[6] and the unexpected isolation of aniline hydrobromide (by Dr. C. E. Vellins in this laboratory) on heating azobenzene-2-sulphenyl bromide with acetone, suggested the present investigation.

At room temperature, azobenzene-2-sulphenyl bromide and its 2-nitro-, 4-nitro-, and 2-benzylthio-derivatives with malonic acid, acetone, or acetophenone in aqueous or

* Part IX, *J.*, 1956, 96.

[1] Zincke, *Ber.*, 1911, **44**, 769; Kharasch, Wehrmeister, and Tigermann, *J. Amer. Chem. Soc.*, 1947, **69**, 1612; for other references, see Kharasch, Potempa, and Wehrmeister, *Chem. Rev.*, 1946, **39**, 269.
[2] Fries and Schürmann, *Ber.*, 1919, **52**, 2170.
[3] Zincke and Röse, *Annalen*, 1914, **406**, 103.
[4] Burawoy, Raymakers, and Turner, *J.*, 1955, 4491.
[5] Kharasch and Bruice, *J. Amer. Chem. Soc.*, 1951, **73**, 3240.
[6] Burawoy *et al.*, *J.*, 1954, 90, 4481; 1955, 3798; 1956, 90, 96.

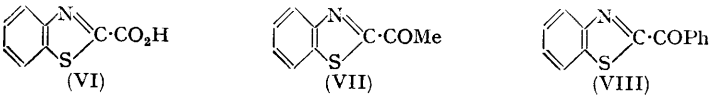
ethanolic solution slowly yield the corresponding (2-arylazophenylthio)acetic acids (III), acetonyl 2-arylazophenyl sulphides (IV), and 2-arylazophenyl phenacyl sulphides (V) respectively, the condensation with malonic acid being accompanied by partial decarboxylation.



(2-Phenylazophenylthio)acetic acid (III; Ar = Ph) could not be isolated, although the reaction was interrupted immediately after complete disappearance of azobenzene-2-sulphenyl bromide (indicated by the absence of the characteristic blue-violet colour due to sodium azobenzene-2-sulphenate on addition of sodium hydroxide to a test sample). Instead, aniline and benzothiazole-2-carboxylic acid (VI) are obtained which are formed by decomposition of the mercaptoacetic acid derivative, the latter reaction being, in this instance, apparently faster than the primary condensation.

Although (2-*p*-nitrophenylazophenylthio)acetic acid (III; Ar = *p*-$NO_2 \cdot C_6H_4$) can be isolated, it also undergoes ready dissociation to *p*-nitroaniline and benzothiazole-2-carboxylic acid, if the reaction mixture is kept for some time at room temperature. In contrast, (2-*o*-nitrophenylazophenylthio)- and (2-*o*-benzylthiophenylazophenylthio)-acetic acid (III; Ar = *o*-$NO_2 \cdot C_6H_4$ and *o*-$Ph \cdot CH_2 \cdot S \cdot C_6H_4$) are rather stable, no dissociation being observed even on prolonged heating of the solutions of the sulphenyl bromides with malonic acid or of the isolated acids in presence of a small amount of hydrochloric acid.

When solutions of azobenzene-2-sulphenyl bromide or its 4-nitro- or 2-benzylthio-derivative are heated with acetone or acetophenone, 2-benzothiazolyl methyl ketone (VII) or 2-benzothiazolyl phenyl ketone (VIII) is obtained in addition to aniline, *p*-nitroaniline, and *o*-benzylthioaniline, respectively. The corresponding sulphides (IV and V) are intermediates in these reactions, since heating their solutions (in acetone or benzene) with a small amount of hydrochloric acid yields the same products. The sulphides obtained from 2-nitroazobenzene-2′-sulphenyl bromide (IV and V; Ar = *o*-$NO_2 \cdot C_6H_4$) are much more stable and are recovered unchanged on prolonged heating of their solutions in presence of acid.



Benzothiazole-2-carboxylic acid (VI), which in the conditions of our experiments separates in an almost pure crystalline state, has been prepared by Hofmann [7] by hydrolysis of its amidine (obtained by the action of an excess of cyanogen on 2-aminothiophenol), and by Reissert [8] by the oxidation of sodium thio-oxanilate ($NHPh \cdot CS \cdot CO_2Na$) with potassium ferricyanide. These authors found that it cannot be readily purified by crystallisation, since it is easily decarboxylated, on heating, with formation of the liquid benzothiazole. Heating of azobenzene-2-sulphenyl bromide and of its 4-nitro-derivative with malonic acid in aqueous or ethanolic solution was, therefore, avoided. The carboxylic acid has been purified through its sparingly soluble stable sodium salt and further characterised as its stable ethyl ester, already obtained by Reissert.[8]

The action of 2-phenylazonaphthalene-1-sulphenyl bromide has also been investigated. However, it is recovered unchanged after prolonged heating with acetone or malonic acid in aqueous or ethanolic solution, condensation being apparently inhibited by steric hindrance.

A few experiments have been carried out with azobenzene-2-sulphenyl chloride and

[7] Hofmann, *Ber.*, 1887, **20**, 2257.
[8] Reissert, *Ber.*, 1904, **37**, 3731.

perchlorate. They behave similarly to the bromide, but the rate of reaction with hot acetone or acetophenone decreases considerably in the order chloride > bromide > perchlorate. This sequence, as well as the mechanism of the reactions, requires elucidation.

Experimental

If not otherwise stated, the reaction times given are approximately those required for complete conversion of the sulphenyl bromides, indicated by the absence of the blue colour developed on addition of sodium hydroxide to a test sample. The identity of the various products isolated was confirmed, if not by analysis, by mixed m. p. determinations.

Acetonyl 2-Phenylazophenyl Sulphide (IV; Ar = Ph).—A solution of azobenzene-2-sulphenyl bromide (1 g.) in acetone (5 c.c.) and water (100 c.c.) was kept for 7 days at room temperature. The precipitate of *acetonyl 2-phenylazophenyl sulphide* was filtered off, washed, and dried (0·85 g., 92%). Crystallisation from aqueous ethanol gave bright orange needles, m. p. 52° (Found : C, 66·7; H, 5·2; N, 10·4. $C_{15}H_{14}ON_2S$ requires C, 66·7; H, 5·2; N, 10·4%). Similar results were obtained with the chloride and perchlorate as starting material.

2-Benzothiazolyl Methyl Ketone (VII).—Azobenzene-2-sulphenyl chloride (1 g.), acetone (5 c.c.), and benzene (100 c.c.) were refluxed for 45 min. The precipitate of almost pure aniline hydrochloride was filtered off (0·35 g., 67%; m. p. 192°; Pinner [9] gives 192°; Ullmann [10] gives 198°). Aniline was identified by conversion into tribromoaniline. Concentration of the filtrate yielded *2-benzothiazolyl methyl ketone* (0·7 g., 90%). Crystallisation from aqueous ethanol or light petroleum (b. p. 60—80°) gave yellow needles, m. p. 109° (Found : C, 60·8; H, 4·1; N, 7·8. C_9H_7ONS requires C, 61·0; H, 3·9; N, 7·9%). Similar results were obtained with the bromide and perchlorate except that the reaction times were 10 and 20 hr., respectively, and on replacement of benzene by acetone as solvent.

Acetonyl 2-phenylazophenyl sulphide (0·5 g.), acetone (20 c.c.), and a drop of concentrated hydrochloric acid were refluxed for 1 hr. After partial removal of the acetone, water was added, and the precipitate of 2-benzothiazolyl methyl ketone was collected (0·25 g., 76%). Crystallisation as before gave yellow needles, m. p. 109°. On addition of bromine to the filtrate, tribromoaniline separated (0·45 g., 73%; m. p. 117°, from ethanol). When heated with acetone in absence of hydrochloric acid, the sulphide was recovered unchanged.

Phenacyl 2-Phenylazophenyl Sulphide (V; Ar = Ph).—A solution of azobenzene-2-sulphenyl bromide (0·5 g.) and acetophenone (5 c.c.) in ethanol (50 c.c.) was kept for about 3 months at room temperature. Water was added, and the precipitated *sulphide* filtered off (0·45 g., 80%). Crystallisation from aqueous ethanol gave orange needles, m. p. 140° (Found : C, 72·1; H, 5·0; N, 8·7. $C_{20}H_{16}ON_2S$ requires C, 72·2; H, 4·8; N, 8·4%). The sulphenyl chloride behaved similarly.

2-Benzothiazolyl Phenyl Ketone (VIII).—Azobenzene-2-sulphenyl chloride (1 g.), acetophenone (5 c.c.), and benzene (100 c.c.) were refluxed for 1 hr. The precipitate of aniline hydrochloride (identified as before) was filtered off (0·45 g., 90%; m. p. 192°). The filtrate was steam-distilled, and the residual *2-benzothiazolyl phenyl ketone* collected (0·75 g., 78%). Crystallisation from aqueous ethanol gave pale yellow needles, m. p. 99° (Found : C, 70·1; H, 3·8; N, 5·8. $C_{14}H_9ONS$ requires C, 70·3; H, 3·8; N, 5·9%). When the sulphenyl bromide was used (reaction time 14 hr.) aniline separated as hydrobromide, m. p. 278°.

Phenacyl 2-phenylazophenyl sulphide (0·2 g.), benzene (20 c.c.), and a drop of concentrated hydrochloric acid were refluxed for 2 hr. After removal of benzene and addition of water, the precipitate of 2-benzothiazolyl phenyl ketone (0·1 g., 70%; m. p. 99°, from dilute ethanol) was collected. The mother-liquor contained aniline. In absence of hydrochloric acid, unchanged sulphide was recovered quantitatively.

Benzothiazole-2-carboxylic Acid (VI).—A solution of azobenzene-2-sulphenyl bromide (1 g.) and malonic acid (1 g.) in water (110 c.c.) was kept at room temperature for 3 days. Benzothiazole-2-carboxylic acid separated as white needles, m. p. 105° (0·6 g., 83%). It was purified *via* its sparingly soluble sodium salt, and obtained as needles, m. p. 108° (Hofmann [7] and Reissert [8] give 108°) (Found : C, 53·4; H, 3·2; N, 7·0. Calc. for $C_8H_5O_2NS$: C, 53·6; H, 2·8; N, 7·8%). It was also characterised as its ethyl ester, needles (from ethanol), m. p. 70° (Reissert [8] gives 70—71°) (Found : C, 58·3; H, 4·3; N, 7·1. Calc. for $C_{10}H_9O_2NS$: C, 58·0; H, 4·3; N, 6·8%). On addition of bromine to the mother-liquor, tribromoaniline separated (1 g., 80%; m. p. 117°, from ethanol). The sulphenyl chloride and perchlorate behaved similarly.

[9] Pinner, *Ber.*, 1881, **14**, 1083.
[10] Ullmann, *Ber.*, 1898, **31**, 1699.

Acetonyl 2-o-*Nitrophenylazophenyl Sulphide* (IV; Ar = *o*-NO_2·C_6H_4).—A solution of 2-nitroazobenzene-2′-sulphenyl bromide (0·5 g.) and acetone (5 c.c.) in water (500 c.c.) was kept for 24 hr. at room temperature. The precipitated *sulphide* was filtered off (0·45 g., 96%). Crystallisation from light petroleum (b. p. 60—80°) or aqueous ethanol gave orange needles, m. p. 115—116° (Found: C, 57·2; H, 4·0; N, 13·4. $C_{15}H_{13}O_3N_3S$ requires C, 57·2; H, 4·1; N, 13·3%). Replacement of the water by benzene (100 c.c.) and 30 hours' refluxing gave the same sulphide (0·3 g., 64%; m. p. 115—116°, from light petroleum) after removal of solvents. The sulphide was recovered unchanged after being heated in acetone with a drop of concentrated hydrochloric acid for 2 hr.

2-o-*Nitrophenylazophenyl Phenacyl Sulphide* (V; Ar = *o*-NO_2·C_6H_4).—A solution of 2-nitroazobenzene-2′-sulphenyl bromide (0·5 g.) and acetophenone (5 c.c.) in ethanol (100 c.c.) was kept at room temperature for 7 days. After addition of water, the precipitate of 2-o-*nitrophenylazophenyl phenacyl sulphide* was filtered off (0·4 g., 71%). Crystallisation from aqueous ethanol gave orange needles, m. p. 121° (Found: C, 63·7; H, 4·2; N, 11·4. $C_{20}H_{15}O_3N_3S$ requires C, 63·7; H, 4·0; N, 11·2%). Replacement of the ethanol by benzene (100 c.c.) and 40 hours' refluxing, followed by removal of the solvent and unchanged acetophenone by steam-distillation, afforded the same sulphide (0·35 g., 62%; m. p. 121°, from aqueous ethanol).

(2-o-*Nitrophenylazophenylthio*)*acetic Acid* (III; Ar = *o*-NO_2·C_6H_4).—A solution of 2-nitroazobenzene-2′-sulphenyl bromide (0·5 g.) and malonic acid (0·5 g.) in water (500 c.c.) was kept at room temperature for 2 days. The precipitated *acid* was collected (0·4 g., 85%). Crystallisation from benzene–light petroleum (b. p. 60—80°) gave a yellow powder, m. p. 168—169° (Found: C, 53·2; H, 3·3; N, 13·4. $C_{14}H_{11}O_4N_3S$ requires C, 53·0; H, 3·4; N, 13·2%). A similar result was obtained on refluxing the same solution for 2 hr. The product was recovered unchanged after its benzene solution had been refluxed with a drop of concentrated hydrochloric acid for 5 hr.

Acetonyl 2-p-*Nitrophenylazophenyl Sulphide* (IV; Ar = *p*-NO_2·C_6H_4).—A solution of 4-nitroazobenzene-2′-sulphenyl bromide (0·5 g.) and acetone (5 c.c.) in water (500 c.c.) was kept at room temperature for 3 days. The precipitated *sulphide* was collected (0·45 g., 96%). Crystallisation from methanol gave orange needles, m. p. 144° (Found: C, 57·1; H, 4·0; N, 13·6. $C_{15}H_{13}O_3N_3S$ requires C, 57·1; H, 4·1; N, 13·3%).

Decomposition of Acetonyl 2-p-*Nitrophenylazophenyl Sulphide.*—4-Nitroazobenzene-2′-sulphenyl bromide (1 g.), acetone (10 c.c.), and benzene (150 c.c.) were refluxed for 8 hr. After removal of the solvent, the residue was extracted with dilute hydrochloric acid, and the insoluble 2-benzothiazolyl methyl ketone collected (0·3 g., 57%; m. p. 109°, from aqueous ethanol). The acidic extract was neutralised with aqueous sodium hydroxide, and the precipitate of *p*-nitroaniline filtered off (0·25 g., 61%; m. p. 147°, from water).

Acetonyl 2-*p*-nitrophenylazophenyl sulphide (0·5 g.), acetone (20 c.c.), and a drop of concentrated hydrochloric acid were refluxed for 1 hr. The solution was worked up as above, yielding 2-benzothiadiazolyl methyl ketone (0·2 g., 71%) and *p*-nitroaniline (0·15 g., 70%). The sulphide was recovered unchanged when heated with acetone in absence of hydrochloric acid.

2-p-*Nitrophenylazophenyl Phenacyl Sulphide* (V; Ar = *p*-NO_2·C_6H_4).—A solution of 4-nitroazobenzene-2′-sulphenyl bromide (0·5 g.) and acetophenone (5 c.c.) in ethanol (100 c.c.) was kept at room temperature for 15 days. Addition of water precipitated the *sulphide*, which was filtered off (0·4 g., 71%). Crystallisation from benzene–light petroleum (b. p. 60—80°) gave orange needles, m. p. 171° (Found: C, 64·2; H, 3·8; N, 11·4. $C_{20}H_{15}O_3N_3S$ requires C, 63·7; H, 4·0; N, 11·2%).

Decomposition of 2-p-*Nitrophenylazophenyl Phenacyl Sulphide.*—4-Nitroazobenzene-2′-sulphenyl bromide (0·5 g.), acetophenone (5 c.c.), and benzene (100 c.c.) were refluxed for 20 hr. Benzene and unchanged acetophenone were removed by steam-distillation, and, after cooling, the insoluble 2-benzothiazolyl phenyl ketone was filtered off (0·2 g., 57%; m. p. 99°, from aqueous ethanol). The filtrate was concentrated, yielding *p*-nitroaniline (0·1 g., 55%; m. p. 147°, from water). A similar result was obtained on refluxing 2-*p*-nitrophenylazophenyl phenacyl sulphide (0·2 g.) in benzene (20 c.c.) with a drop of concentrated hydrochloric acid for 2 hr. When heated without the acid, the sulphide was recovered unchanged.

(2-p-*Nitrophenylazophenylthio*)*acetic Acid* (III; Ar = *p*-NO_2·C_6H_4).—A solution of 4-nitroazobenzene-2′-sulphenyl bromide (0·5 g.) and malonic acid (0·5 g.) in water (500 c.c.) was kept for 2 days at room temperature. The precipitated *acid* was collected (0·2 g., 43%). Crystallisation from benzene–light petroleum (b. p. 60—80°) gave a yellow powder, m. p. 170° (Found: C, 53·6; H, 3·2; N, 13·6. $C_{14}H_{11}O_4N_3S$ requires C, 53·0; H, 3·4; N, 13·2%).

Decomposition. The preceding experiment was repeated, but, after complete disappearance

of the sulphenyl bromide, the solution was kept for another 5 days at room temperature. The yellow precipitate disappeared slowly, being replaced by white needles of benzothiazole-2-carboxylic acid which were filtered off (0·03 g., 11%; m. p. 106—107°). The filtrate was concentrated and neutralised with sodium hydroxide, and the precipitate of almost pure *p*-nitroaniline collected (0·16 g., 78%; m. p. 146°).

Acetonyl 2-o-*Benzylthiophenylazophenyl Sulphide* (IV; Ar = *o*-Ph·CH_2·S·C_6H_4).—A solution of 2-benzylthioazobenzene-2′-sulphenyl bromide (0·5 g.) and acetone (10 c.c.) in ethanol (50 c.c.) was kept at room temperature for 24 hr. Water was added, and the precipitated *sulphide* was filtered off (0·4 g., 83%). Crystallisation from ethanol gave orange needles, m. p. 129° (Found: C, 67·3; H, 5·2; N, 7·4. $C_{22}H_{20}ON_2S_2$ requires C, 67·3; H, 5·1; N, 7·1%).

Decomposition. The preceding experiment was repeated, but, after disappearance of the sulphenyl bromide, the solution was heated for 10 min. at 60° and kept for another 24 hr. at room temperature. The solution was concentrated under reduced pressure, water and dilute hydrochloric acid were added, and the mixture was extracted with ether, from which 2-benzothiazolyl methyl ketone was obtained (0·1 g., 47%; m. p. 109°, from aqueous ethanol). The aqueous layer was made alkaline and extracted with ether. Evaporation of the solvent yielded *o*-benzylthioaniline (0·17 g., 65%; m. p. 46°, from light petroleum).

2-o-*Benzylthiophenylazophenyl Phenacyl Sulphide* (V; Ar = *o*-Ph·CH_2·S·C_6H_4).—A solution of 2-benzylthioazobenzene-2′-sulphenyl bromide (0·5 g.) and acetophenone (5 c.c.) in ethanol (50 c.c.) was kept at room temperature for 2 days. The precipitated *sulphide* was collected (0·4 g., 73%). Crystallisation from ethanol gave orange needles, m. p. 147° (Found: C, 71·5; H, 4·8; N, 5·5. $C_{27}H_{22}ON_2S_2$ requires C, 71·4; H, 4·8; N, 6·1%).

Decomposition of the sulphide. A solution of 2-benzylthioazobenzene-2′-sulphenyl bromide (0·5 g.) and acetophenone (5 c.c.) in benzene (100 c.c.) was refluxed for 14 hr., cooled, and extracted with dilute hydrochloric acid. The extract was neutralised, and the precipitate of *o*-benzylthioaniline collected (0·12 g., 46%; m. p. 46°, from light petroleum). The benzene layer was steam-distilled, and the residual insoluble 2-benzothiazolyl phenyl ketone was filtered off (0·14 g., 44%; m. p. 99°, from aqueous ethanol).

(2-o-*Benzylthiophenylazophenylthio*)*acetic Acid* (VI; Ar = *o*-Ph·CH_2·S·C_6H_4).—A solution of 2-benzylthioazobenzene-2′-sulphenyl bromide (0·5 g.) and malonic acid (0·5 g.) in water (10 c.c.) and ethanol (100 c.c.) was kept at room temperature for 24 hr. The precipitated *acid* was filtered off (0·35 g., 73%). Crystallisation from benzene or ethanol gave a yellow powder, m. p. 158° (Found: C, 63·7; H, 4·8; N, 7·6. $C_{21}H_{18}O_2N_2S_2$ requires C, 63·9; H, 4·5; N, 7·1%). The preceding experiment was repeated, but the solution refluxed for 1 hr. On cooling, the almost pure mercaptoacetic acid derivative separated (0·41 g., 85%; m. p. 158°).

The product (0·2 g.), benzene (20 c.c.), and a drop of concentrated hydrochloric acid were refluxed for 5 hr. Unchanged starting material was recovered almost quantitatively.

Methyl ester. A solution of the mercaptoacetic acid derivative (0·2 g.) and diazomethane (~0·2 g.) in ether (60 c.c.) was kept for 20 hr. and then concentrated to a small volume. Addition of light petroleum precipitated the *ester* (0·17 g., 82%). Crystallisation from methanol gave orange-yellow needles, m. p. 128° (Found: C, 65·1; H, 5·1. $C_{22}H_{20}O_2N_2S_2$ requires C, 64·7; H, 4·9%).

Attempted Condensation of 2-Phenylazonaphthalene-1-sulphenyl Bromide with Acetone or Malonic Acid.—Solutions of the sulphenyl bromide (0·5 g.) and acetone (10 c.c.) or malonic acid (1 g.) in water (100 c.c.) were kept at room temperature for 3 months or refluxed for 20—30 hr. Unchanged starting material was recovered almost quantitatively. The same result was obtained when the water was replaced by acetone or benzene.

We thank Mr. B. Manohin for microanalyses.

College of Technology, University of Manchester. [*Received, September 23rd,* 1955.]