Preparation and Spectroscopic Properties of
## 2-Benzothiazolyl Araldehyde Hydrazones

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Notwithstanding its tendency toward air oxidation in solution, 2-hydrazinobenzothiazole **I** reacted with aromatic aldehydes in ethanol to give the corresponding hydrazones **III-XV** in high yields and analytical purity. In related examples, acylation took place under similar conditions to produce hydrazides **XVI-XX**. The near-infrared bands of the absorption spectra of the araldehyde hydrazones have been associated with charge transfer and appeared to correlate with structural elements of the compounds in a way suggesting that the charge transfer was intermolecular.

Although considerable interest has recently attended on its utility as a highly reactive reagent for the microdetection of certain aldehydes [1], for the colorimetry of sugars and 17-ketosteroids [2], for the detection of formaldehyde at very low levels [3], and for dyeing polyester yarns [4], not a great deal of work has been done in a systematic way to explore the reactions of 2-hydrazinobenzothiazole (**I**) with aldehydes. Possessing a number of sites available for aromatic substitution, reduction, hydrogenolytic cleavage
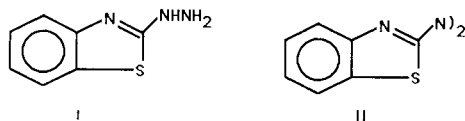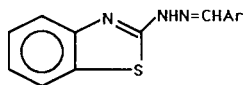

and hydrolysis, hydrazones derived from **I** represent potentially attractive intermediates for synthesis. Because some polyfunctional heterocyclic hydrazines display unusual chemoselectivity in their reactions [5,6], our interest was further focussed by the report [3] that aromatic aldehydes failed to condense with **I** in specific analytical procedures, although aliphatic aldehydes did react.

Indeed, compound **I** is a sensitive material. Its deliberate chemical oxidation can lead to the symmetrical heteroaromatic azo compound **II** under very mild conditions [7,8,9], and solutions of **I** tend to decompose in air; we found, for example, that dimethyl sulfoxide solutions take on an intense blue coloration within seconds of
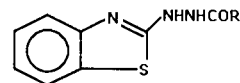
preparation and experience concomitant major changes in the absorption spectrum over time (see Experimental).

On the other hand, we have now found that, under our conditions, decomposition in aqueous ethanol is not so rapid as to prevent adequate reaction with aromatic aldehydes. Thus treatment of **I** with the appropriate araldehyde in boiling alcohol led to the formation of hydrazones **III-XV** in satisfactory yields; the insoluble crystalline products could be isolated directly from the reaction medium in analytical purity. In a typical example, 4-chlorobenzaldehyde (3.34 equivalents) was refluxed (4.5 hours) with **I** (2.00 equivalents) in 95% ethanol, the reaction mixture was allowed to cool and stand over night, and the resultant pale yellow crystals were gravity filtered to give **IV** (85%) without need for further purification. In each case examined, the reaction could be tested for completion by observing the highly characteristic trio of strong infrared bands in the 1600 cm⁻¹ region corresponding to the hydrazone product (see Experimental).

In related examples under similar reaction conditions, addition of neat carboxylic acid anhydrides to freshly prepared solutions of **I** in ethanol at reflux allowed for the controlled formation [10] of monohydrazides **XVI-XX**, derivatives which we found to be stable over many months. In a representative case, **I** (1.8 mmoles) was brought to reflux in absolute ethanol to give a homogeneous yellow


Compound	Ar
III	Ph
IV	4-ClPh
V	3-ClPh
VI	2-ClPh
VII	4-CH₃OPh
VIII	4-NO₂Ph
IX	3-NO₂Ph

Compound	Ar
X	2-NO₂Ph
XI	1-Naphth
XII	2-Naphth
XIII	4-BrPh
XIV	4-Me₂NPh
XV	4-CH₃Ph

Compound	R
XVI	Me
XVII	Et
XVIII	Pr
XIX	iPr
XX	Bu

solution. Butyric anhydride (1.1 equivalents) was added dropwise, giving a vigorous reaction and discharging the yellow color. After a further short reflux period (20 minutes), the mixture was cooled, inducing rapid crystallization of **XVIII** (51%).

The near-infrared bands of the absorption spectra of the araldehyde hydrazones **III-XV** merit some comment (see Experimental for individual data). Although the application of near-infrared spectroscopy to structural problems in organic chemistry is a field still in its formative stages, the method may have considerable potential for the study of intermolecular effects [11]. We have observed that for saturated solutions in ethanol each of our compounds displays a strong broad peak in the 800 nm region (log ϵ ca. 5), in accord with our previous observation of such bands in the spectra of other heterocyclic hydrazones [12]. Several facts now lead us to ascribe this near-infrared peak to intermolecular charge transfer. The absorption appears to be closely tied to both the nature and position of substituents, particularly where the latter are capable of inducing considerable polarization of the molecule by interaction with π bonds. Thus compound **III** (Ar = Ph) absorbs near 760 nm, whereas **VIII** (Ar = 4-NO$_2$Ph) has a peak at 869 nm, a substantial difference which we attribute to the polarizing effect through the π bonding system of the strong electron-withdrawing nitro group. In **X** (Ar = 2-NO$_2$Ph, λ = 807 nm), the ortho substituent may hinder coplanarity of the phenyl ring with the rest of the π system, reducing the polarizing influence of the nitro group overall and thus the value of the wavelength maximum. In **IX** (Ar = 3-NO$_2$Ph, λ = 770 nm) mesomeric interactions of the nitro group would not occur. By way of precedent, near-infrared absorptions in the 700-1100 nm range have recently been noted [13] for charge transfer complexes of carbazole **XXI** with various acceptors. Reference to a
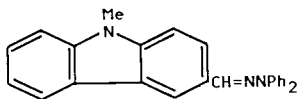
XXI

simpler hydrazine model system may also be useful in understanding our spectra. We have found that the absorption spectrum of 4-nitrophenylhydrazine in ethanol has a maximum in the 800 nm region. In dilute solutions (10^{-4} M), the peak is bell-shaped and occurs near 801 nm; but at increasing concentrations (10^{-3} M or higher) the peak becomes asymmetric, and the maximum is progressively redshifted, indicating the incremental dependence of the position of the wavelength maximum on concentration (see Experimental for further data). Such behavior may well be a consequence of interactions allowing for charge transfer, and one possible highly-simplified depiction of these would have individual molecules stacked in solution

in a head-to-tail arrangement, permitting intermolecular alignment of partially positive centers with partially negative ones [14]. It would be expected that as the concentration were increased, donor-acceptor interactions would be more effectively realized and the charge transfer transition would move to longer wavelength [15]. Continuing this theme among the present benzothiazolylhydrazones, we have found that the absorption maxima of the para-substituted compounds seem to correlate with Hammett sigma values in a second order fit. In this way **III, IV, VII, VIII** and **XIII**, *viz.*, materials in which the substituent is not expected to react with solvent, have maxima as a function of sigma in a curvilinear fit of order 2 with correlation coefficient of 0.999 (see Experimental for regression method), a fit which we believe to be consistent with intermolecular charge transfer. Although the arylhydrazines and benzothiazolylhydrazones do not bear any full charges and are thus structurally quite different from such cationic xanthene dyes as Rose Bengal, our spectroscopic results are qualitatively reminiscent of non-Beer's law effects for the latter observed under conditions allowing for aggregation [16-19].

EXPERIMENTAL

Elemental analyses were performed by Galbraith Laboratories, Knoxville, Tennessee, and were obtained for all new compounds. Melting points were taken in open capillary tubes using a Mel-Temp apparatus and are uncorrected. Infrared spectra were recorded on a Perkin-Elmer 1310 spectrophotometer as Nujol mulls. Ultraviolet-visible-near-infrared spectra were run on saturated solutions in ethanol using standard 10 mm quartz cuvettes (International Crystal Laboratories) on a GCA-McPherson 707 UV-VIS-NIR instrument fitted with a Cyborg data collection system. Absolute alcohol was purchased from Baker Chemical Company; 95% ethanol was obtained from Pharmaco Products, and both were used without further purification. Carboxylic acid anhydrides from Aldrich Chemical Company were used as received, as was 2-hydrazinobenzothiazole from Eastman Organic Chemicals. Although the latter material has a substantial shelf life as the dry solid, its solutions tend to decompose in air, a tendency which is considerably accelerated in such solvents as dimethyl sulfoxide. Even very dilute solutions of **I** in DMSO at ambient temperature take on an intense blue color within seconds of preparation, while the absorption spectrum shows the corresponding formation and increase in intensity of a very strong band at 750 nm, consistent with **II**.

Preparation of Araldehyde Hydrazones. General Procedure. 4-Chlorobenzal of 2-Hydrazinobenzothiazole (**IV**).

4-Chlorobenzaldehyde (0.470 g, 3.34 mmoles) was dissolved in 95% ethanol (25 ml), and the solution was added to a 100 ml round bottom flask containing 2-hydrazinobenzothiazole (**I**, 0.330 g, 2.00 mmoles) and a few boiling chips. The mixture was brought to reflux, and this temperature was maintained for 4.5 hours. During the course of the reflux period, a pale yellow crystalline product was steadily formed. The mixture was allowed to cool and to stand overnight, following which the solid material

was gravity filtered and permitted to dry in the air to yield **IV**, 0.576 g, 85%; mp 274-275°; ir ν 1620, 1600, 1575 cm⁻¹; uv-vis-nir: λ 270, 305, 773 nm. Compound **IV** did not require further purification prior to analysis. All of the congeners of **IV** had low solubility in ethanol, and absorption spectra were run on saturated solutions.

Anal. Calcd. for $C_{14}H_{10}ClN_3S$: C, 58.43; H, 3.50. Found: C, 58.30; H, 3.60.

Benzal of 2-Hydrazinobenzothiazole (III).

This material was obtained in 55% yield, mp 226-229°; ir: ν 1620, 1600, 1575 cm⁻¹; uv-vis-nir: λ 258, 303, 760 nm.

Anal. Calcd. for $C_{14}H_{11}N_3S$: C, 66.38; H, 4.38. Found: C, 66.59; H, 4.50.

3-Chlorobenzal of 2-Hydrazinobenzothiazole (V).

The compound was obtained in 96% yield, mp 245-246°; ir: ν 1620, 1600, 1550 cm⁻¹; uv-vis-nir: λ 260, 335, 774 nm.

Anal. Calcd. for $C_{14}H_{10}ClN_3S$: C, 58.43; H, 3.50. Found: C, 58.15; H, 3.62.

2-Chlorobenzal of 2-Hydrazinobenzothiazole (VI).

This hydrazone was filtered off in 93% yield, mp 244-245°; ir: ν 1620, 1595, 1560 cm⁻¹; uv-vis-nir: λ 250, 347, 765 nm.

Anal. Calcd. for $C_{14}H_{10}ClN_3S$: C, 58.43; H, 3.50. Found: C, 58.49; H, 3.62.

4-Methoxybenzal of 2-Hydrazinobenzothiazole (VII).

The substance was isolated in 59% yield, mp 188-189°; ir: ν 1620, 1600, 1570 cm⁻¹; uv-vis-nir: λ 260, 765 nm.

Anal. Calcd. for $C_{15}H_{13}N_3SO$: C, 63.58; H, 4.62. Found: C, 63.68; H, 4.69.

4-Nitrobenzal of 2-Hydrazinobenzothiazole (VIII).

The benzal was obtained in 89% yield, mp 284-285°; ir: ν 1620, 1600 (sh) 1565 cm⁻¹; uv-vis-nir: λ 270, 371, 869 nm.

Anal. Calcd. for $C_{14}H_{10}N_4SO_2$: C, 56.37; H, 3.38. Found: C, 56.29; H, 3.43.

3-Nitrobenzal of 2-Hydrazinobenzothiazole (IX).

The yield of this compound was 88%, mp 259-260°; ir: ν 1618, 1599, 1577 cm⁻¹; uv-vis-nir: λ 244, 336, 770 nm.

Anal. Calcd. for $C_{14}H_{10}N_4SO_2$: C, 56.37; H, 3.38. Found: C, 56.25; H, 3.29.

2-Nitrobenzal of 2-Hydrazinobenzothiazole (X).

This substance was produced in 79% yield, mp 261-262°; ir: ν 1623, 1606, 1575 cm⁻¹; uv-vis-nir: λ 231, 366, 807 nm.

Anal. Calcd. for $C_{14}H_{10}N_4SO_2$: C, 56.37; H, 3.38. Found: C, 56.40; H, 3.59.

1-Naphthal of 2-Hydrazinobenzothiazole (XI).

This compound was obtained in 94% yield, mp 243-244°; ir: ν 1613 (sh), 1599, 1560 cm⁻¹; uv-vis-nir: λ 292, 786 nm.

Anal. Calcd. for $C_{18}H_{13}N_3S$: C, 71.26; H, 4.32. Found: C, 70.89; H, 4.64.

2-Naphthal of 2-Hydrazinobenzothiazole (XII).

This material was isolated in 99% yield, mp 258-261°; ir: ν 1612 (sh), 1595, 1562 cm⁻¹; uv-vis-nir: λ 273, 320, 800 nm.

Anal. Calcd. for $C_{18}H_{13}N_3S$: C, 71.26; H, 4.32. Found: C, 70.97; H, 4.25.

4-Bromobenzal of 2-Hydrazinobenzothiazole (XIII).

The substance was filtered off in 97% yield, mp 280-281°; ir: ν 1620 (br) cm⁻¹; uv-vis-nir: λ 360, 774 nm.

Anal. Calcd. for $C_{14}H_{10}N_3SBr$: C, 50.61; H, 3.03. Found: C, 50.50; H, 3.06.

4-Dimethylaminobenzal of 2-Hydrazinobenzothiazole (XIV).

The compound was produced inl 70% yield, mp 239-241°; ir: ν 1620 (br) cm⁻¹; uv-vis-nir: λ 367, 785 nm.

Anal. Calcd. for $C_{16}H_{16}N_4S$: C, 64.84; H, 5.44. Found: C, 64.38; H, 5.59.

4-Tolual of 2-Hydrazinobenzothiazole (XV).

The material was obtained in 76% yield, mp 236-237°; ir: ν 1640 (br) cm⁻¹; uv-vis-nir: λ 766 nm.

Anal. Calcd. for $C_{15}H_{13}N_3S$: C, 67.39; H, 4.90. Found: C, 67.13; H, 5.00.

1-Acyl-2-benzothiazolylhydrazines. General Procedure. 1-Butyryl-2-benzothiazolylhydrazine (XVIII).

A mixture of 2-hydrazinobenzothiazole **I**, 0.301 g, 1.82 mmoles) and absolute ethanol (11 ml) was brought to reflux; after a few minutes the solution was clear and yellow. Butyric anhydride (0.32 ml. 1.1 equivalents) was added dropwise through the reflux condenser, causing the reaction mixture to boil more vigorously and eventually discharging the yellow color. After continuing the reflux for 20 minutes further, the mixture was cooled, and crystallization began almost immediately. The white solid was collected to give **XVIII**, 0.218 g, 51%, mp 180-182°; ir: ν 3332, 1672, 1624, 1499, 1275, 1240, 963, 763, 736 cm⁻¹; uv: λ 245, 275, 287, 297 nm.

Anal. Calcd. for $C_{11}H_{13}N_3SO$: C, 56.15; H, 5.57. Found: C, 55.96; H, 5.72.

In each of the following examples, characteristic infrared peaks were observed near ν 3330, 1670, 1625 and 1500 cm⁻¹; and uv absorptions were noted near λ 245, 275, 287 and 298 nm. All of the substances were white crystalline solids.

1-Acetyl-2-benzothiazolylhydrazine (XVI).

This material was formed in 84% yield, mp 225-228°; ir and uv data were as noted in the representative procedure for **XVIII**.

Anal. Calcd. for $C_9H_9N_3SO$: C, 52.16; H, 4.38. Found: C, 51.97; H, 4.30.

1-Propionyl-2-Benzothiazolylhydrazine (XVII).

The compound was isolated in 52% yield, mp 225-227°; ir and uv as above.

Anal. Calcd. for $C_{10}H_{11}N_3SO$: C, 54.28; H, 5.01. Found: C, 53.93; H, 5.15.

1-Isobutyryl-2-benzothiazolylhydrazine (XIX).

The product was filtered off in 54% yield, mp 178-179°; ir and uv as above.

Anal. Calcd. for $C_{11}H_{13}N_3SO$: C, 56.15; H, 5.57. Found: C, 56.11; H, 5.61.

1-Valeryl-2-benzothiazolylhydrazine (XX).

The compound was obtained in 79% yield, mp 192-193°; ir and uv as above.

Anal. Calcd. for $C_{12}H_{15}N_3SO$: C, 57.57; H, 6.04. Found: C, 57.71; H, 6.14.

Note on Curvilinear Polynomial Regression Analysis.

Compounds bearing para substituents were chosen such that reactions with solvent were not expected. In the listing given below, Hammett sigma values [20] for the appropriate benzylidene substitutent groups were employed as **X** coordinates, while the near-infrared absorption data for compounds **III**, **IV**, **VII**, **VIII** and **XIII** were used as corresponding Y coordinates, in a statistical program adapted from J. C. Davis [21]. Salient features of the computer run are as follows:

Input X-Y Pairs: (Entry, *para*-substituent, X, Y), (1, H, 0, 760), (2, Cl, 0.23, 773), (3, CH_3O, −0.27, 765), (4, NO_2, 0.78, 869), (5, Br, 0.23, 774), (6, CH_3, −0.17, 766).

Input Order of Equation = 2

Parameters of the Regression Equation: A = 152.579, B = 19.0232, C = 761.213

Total Sums of Squares = 8705.2500

Sums of Squares Due to Regression = 8685.5000

Sums of Squares Due to Deviation = 19.7500

Standard Deviation of Residuals = 2.222049

Correlation Coefficient = 0.998865

Near-infrared Spectra of Substituted Arylhydrazines.

All of the materials examined displayed non-Beer's law behavior at higher concentrations, although the most pronounced effect was noted for the nitro compound. Spectra were obtained in absolute ethanol on freshly prepared solutions. For each compound, the concentration, wavelength maximum and band shape are reported. 4-Nitrophenylhydrazine (10^{-4} M, 801 nm, Gaussian bell); (10^{-3} M, 862 nm, asymmetric); (10^{-2} M, 921 nm asymmetric). 4-Tolylhydrazine (10^{-3} M, 770 nm, asymmetric). 4-Chlorophenylhydrazine (10^{-3} M, 755 nm, asymmetric). Phenylhydrazine (10^{-3} M, 707 nm, asymmetric).

Acknowledgments.

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