[Chem. Pharm. Bull. 23(2) 258—263 (1975)]

UDC 547.818.057 : 547.379.1.04

Stable Sulfur Ylides. III.[1] Reaction of Stable Sulfonium Allylides and Oxosulfonium Allylides with Alkoxides

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(Received June 6, 1974)

Treatment of dimethyloxosulfonium 1-benzoyl-3,3-diacylallylides (Ia—b) with sodium ethoxide in ethanol or sodium methoxide in methanol gave several thiabenzene 1-oxide derivatives (IIa—b, IIIa—d). Similar treatment of dimethyloxosulfonium 1-benzoyl-3-acetylallylide (Ic) afforded 1,5-dimethyl-2-benzoylthiabenzene 1-oxide (IIIe) in a good yield. On the other hand, treatment of dimethyl- and tetramethylene-sulfonium 1-benzoyl-3,3-diacylallylides (Va—c) with sodium ethoxide in ethanol gave biphenyl derivatives (VIa—c).

Several thiabenzene 1-oxide derivatives were obtained by Hortmann,[3] Kishida,[4] Cram,[5] Harris,[6] and Holt[7] by the reaction of dimethyloxosulfonium methylide with acetylene or alkoxyethylene derivatives. In 1966, Kishida reported the reaction of stable dimethyloxosulfonium 1-benzoyl-2-phenyl-3-ethoxycarbonylallylide[8] with sodium ethoxide to give the corresponding thiabenzene 1-oxide. Recently, Tamura, *et al.*[9] reported that 1-methyl-4-acylthiabenzene 1-oxides were produced by the reaction of dimethyloxosulfonium methylide with 1-alkoxy-2,2-diacylethylenes, and in some cases of this reaction, allylide intermediate was isolated.

Previously, we reported the syntheses of stable oxosulfonium and sulfonium allylides.[1] We reported herein the reaction of these allylides with alkoxides. When oxosulfonium allylides were treated with alkoxides, new classes of thiabenzene 1-oxides were obtained. On the other hand, sulfonium allylides were converted to biphenyl derivatives under the same reaction condition.

The reaction of dimethyloxosulfonium 1-benzoyl-3,3-diacetylallylide (Ia) with sodium ethoxide in ethanol gave 1,3-dimethyl-4-acetylthiabenzene 1-oxide (IIa, 36.4%), 1,5-dimethyl-2-benzoyl-4-acetylthiabenzene 1-oxide (IIIa, 46.3%), and benzoic acid. IIa was identified with an authentic sample[9] by mixed melting point and comparison of infrared (IR) spectra. The structure of IIIa was determined from the elemental and spectral analyses. On the other hand, IIIa was obtained as a sole product in 93.7% yield when Ia was treated with sodium methoxide in methanol instead of sodium ethoxide in ethanol. The same reaction was attempted with dimethyloxosulfonium 1-benzoyl-3-acetyl-3-ethoxycarbonylallylide (Ib) which can be expected to give two different intramolecular cyclization products. Actually, two

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[1] Part II: M. Watanabe, T. Kinoshita, and S. Furukawa, *Chem. Pharm. Bull.* (Tokyo), **23**, 82 (1975).
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[3] *a*) A.G. Hortmann, *J. Am. Chem. Soc.*, **87**, 4972 (1965); *b*) A.G. Hortmann and R.L. Harris, *ibid.*, **93**, 2471 (1971).
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[6] *a*) T.M. Harris, C.M. Harris, and J.C. Cleary, *Tetrahedron Lett.*, **1968**, 1427; *b*) *Idem, J. Org. Chem.*, **39**, 72 (1974).
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[8] *a*) Y. Kishida and J. Ide, *Tetrahedron Lett.*, **1966**, 1787; *b*) *Idem, Chem. Pharm. Bull.* (Tokyo), **16**, 784 (1968).
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kinds of thiabenzene 1-oxide (IIIb and, IIIc, IIId and IIb) were obtained by the reaction of Ib with sodium ethoxide. The structures of these compounds were determined from their elemental and spectral analyses. In additional support, the treatment of IIIb with acetic anhydride gave the corresponding O-acetyl compound (IV), and IIIc was converted into IIId almost quantitative by the reaction with sodium ethoxide in ethanol. IIId was also decarboxylated to IIIe with sulfuric acid in a good yield. When sodium methoxide used instead of sodium ethoxide as the base, transesterification was observed. The reaction of Ib with sodium methoxide in methanol afforded 1,3-dimethyl-4-methoxycarbonylthiabenzene 1-oxide (IIc), IIIb and IIId.

Similar treatment of dimethyloxosulfonium 1-benzoyl-3-acetylallylide (Ic) gave 1,5-dimethyl-2-benzoylthiabenzene 1-oxide (IIIe) in 90% yield. The structure of IIIe was confirmed by elemental and spectral analyses. Particularly, the IR spectrum of IIIe showed a strong absorption at 1590 cm^{-1} which was characteristic of the ylide carbonyl.

Table I shows the nuclear magnetic resonance (NMR) spectral data of ring protons in all the thiabenzene 1-oxide derivatives obtained here and discussed below. All of Hb protons appear in the aromatic proton region, and Ha, Hd, and Hc protons in the vinyl proton region. In the NMR spectrum of IIIe, addition of deuterium oxide to deuteriochloroform solution of IIIe produced decrease in the intensity of signals at 5.62 ppm for Hd proton and at 5.93 ppm for Hc proton peaks, and a doublet signal at 7.20 ppm for Hb proton changed into a singlet at 7.19 ppm. Similar experiment was carried out on IIc, in which deuterium exchange was slower than IIIe. After 72 hr from the addition of deuterium oxide, its NMR spectrum showed disappearance of the signals at 5.52 and 5.65 ppm for Hc and Ha protons, respectively, and a doublet signal of 8.00 ppm for Hb proton changed into a singlet. However, deuterium exchange was not observed under the same experimental condition in IIIc which possessed electron-withdrawing substitutents at both C-2 and C-4 positions. These results reveal that protons in the vinyl proton region undergo exchange of hydrogen for deuterium by the addition of deuterium oxide except for ring protons of IIIc, but no change is observed for protons in the aromatic proton region. On the basis of these observations, it seemed reasonable to assume that the bonding of sulfur with C-2 of C-6 in IIIc would have a more predominant yllen-like character than these bonds in IIIe or IIc.

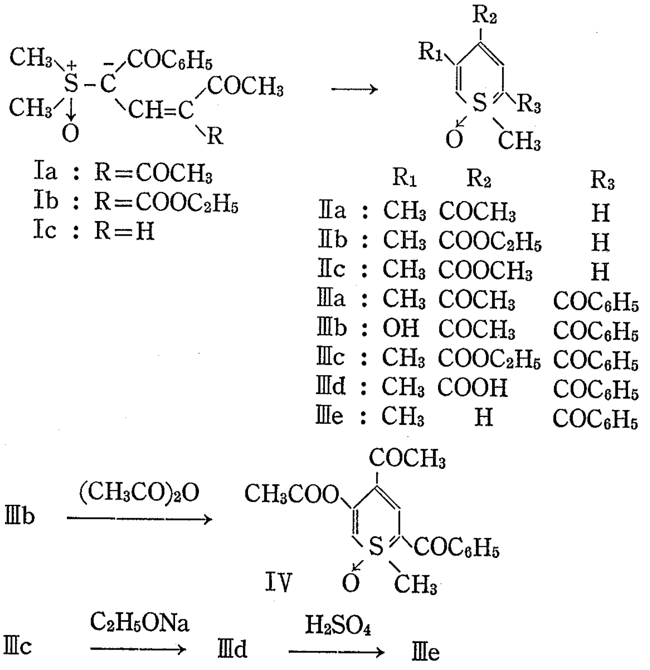
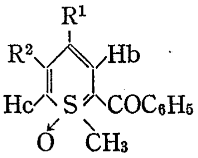


Chart 1

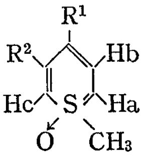
When the same reaction were carried out on dimethylsulfonium allylides in place of dimethyloxosulfonium allylides, different products were obtained. The reaction of dimethylsulfonium 1-benzoyl-3,3-diacetylallylide (Va) with sodium ethoxide in ethanol gave exclusively 1-phenyl-2-methylthio-4-acetyl-5-hydroxybenzene (VIa). VIa was easily converted into the corresponding O-acetyl compound (VII) with acetic anhydride in the usual manner, and into the corresponding sulfone derivative (VIII) with hydrogen peroxide at room temperature. The structures of VIa, VII, and VIII were confirmed from their elemental analyses and spectral data.

The IR spectrum of VIa showed a carbonyl absorption band at 1639 cm^{-1}. This low frequency shift of the carbonyl absorption band is due to a strong hydrogen bond between the acetyl and hydroxyl groups, because the IR spectrum of VII showed the carbonyl absorption at 1698 cm^{-1}, in a higher frequency. The ultraviolet (UV) absorption spectrum of VIa showed maxima at 223 nm (log ε, 4.38), 260 nm (log ε, 3.45), and 370 nm (log ε, 3.45), corresponding to the biphenyl chromophore. In the NMR spectrum of VIII, the signals of C-3 proton (8.61 ppm) and methylsulfone protons (2.75 ppm) appeared at a relatively lower

TABLE I. NMR Spectral Data[a)]

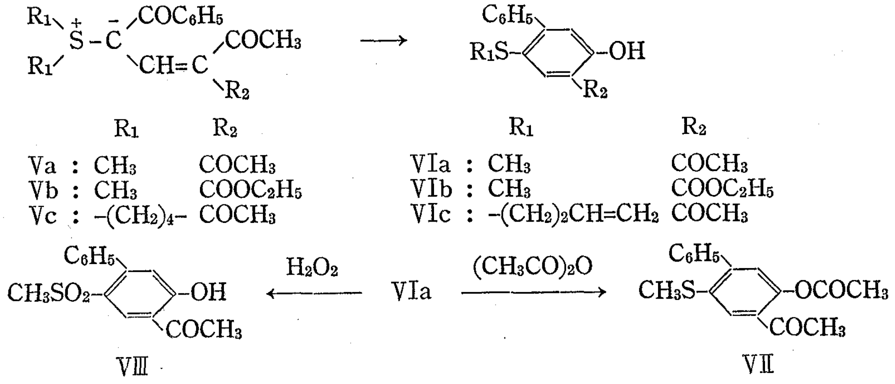


Compound No.	R^1	R^2	Hb	Hc	Hd
IIIa	$COCH_3$	CH_3	8.07[b)]	5.96	—
IIIb	$COCH_3$	OH	8.05	5.42	—
IIIc	$COOC_2H_5$	CH_3	8.49	5.91	—
IIId	COOH	CH_3	8.43	6.12	—
IIIe	Hd	CH_3	7.20 (J_{bd}[b)]=10)	5.93 (J_{cd}=1.8)	5.62 (J_{bd}= 10) (J_{cd}=1.8)



Compound No.	R^1	R^2	Ha	Hb	Hc
IIa	$COCH_3$	CH_3	5.60—5.75	7.80	5.60—5.75
IIb	$COOC_2H_5$	CH_3	5.63 (J_{ab}=9) (J_{ac}=4)	8.05 (J_{ab}=9)	5.53 (J_{ac}=4)
IIc	$COOCH_3$	CH_3	5.65 (J_{ab}=9) (J_{ac}=4)	8.00 (J_{ab}=9)	5.52 (J_{ac}=4)

a) 100 MHz with TMS as internal reference
b) Chemical shifts are expressed in δ value and coupling constants in Hz.



	R_1	R_2
Va	CH_3	$COCH_3$
Vb	CH_3	$COOC_2H_5$
Vc	$-(CH_2)_4-$	$COCH_3$

	R_1	R_2
VIa	CH_3	$COCH_3$
VIb	CH_3	$COOC_2H_5$
VIc	$-(CH_2)_2CH=CH_2$	$COCH_3$

Chart 2

magnetic field compared with the corresponding signals in VIa (C-3 proton, 7.80 ppm; methylthio, 2.22 ppm).

Similar treatment of dimethylsulfonium 1-benzoyl-3-acetyl-3-ethoxycarbonylallylide (Vb) and tetramethylenesulfonium 1-benzoyl-3,3-diacetylallylide (Vc) afforded 1-phenyl-2-methylthio-4-ethoxycarbonyl-5-hydroxybenzene (VIb) in 50% yield, accompanied with a small amount of acidic material, and 1-phenyl-2-(3-butenylthio)-4-acetyl-5-hydroxybenzene (VIc) in 79% yield, respectively. The structure of VIc was determined by NMR spectrum and supported by IR and UV spectra. In the NMR spectrum of VIc, new signals appeared at 4.18—4.98 ppm (2H, multiplet) and 5.45—5.79 ppm (1H, multiplet) due to terminal vinyl protons. This observation indicated that tetramethylene sulfide ring was cleaved to butenyl-

Table II. Thiabenzene 1-Oxide Derivatives

Compound No.	Formula	mp (°C)	Yield (%)	Analysis (%)		IR cm^{-1} (KBr)	UV λ_{max}^{EtOH} nm (log ε)
				Calcd.	Found		
IIa	$C_9H_{12}O_2S$	126[a]	36.4			ν_{CO} 1618	300(4.15)
IIb	$C_{10}H_{14}O_3S$	92[b]	trace			ν_{CO} 1685	280(4.43) 318(3.80)
IIc	$C_9H_{12}O_3S$	120[b]	10	C 53.99 H 6.04	54.48 6.05	ν_{CO} 1690	280(4.40) 318(3.78)
IIIa	$C_{16}H_{16}O_3S$	147[c]	93.7	C 66.66 H 5.59	66.63 5.73	ν_{CO} 1645	247(4.53) 289(4.41) 374(4.32)
IIIb	$C_{15}H_{14}O_4S$	147[a]	30	C 62.06 H 4.86	61.63 5.00	ν_{CO} 1620	242(4.19) 272(4.27) 360(4.17)
IIIc	$C_{17}H_{18}O_4S$	159[b]	10	C 64.14 H 5.70	64.21 5.61	ν_{CO} 1615 1700	243(4.45) 270(4.20) 377(4.11)
IIId	$C_{15}H_{14}O_4S$	224[d]	40	C 62.06 H 4.86	62.29 4.76	ν_{CO} 1609 1656	227(4.18) 283(4.43) 378(4.09)
IIIe	$C_{14}H_{14}O_2S$	135[c]	91.8	C 68.28 H 5.73	68.03 5.40	ν_{CO} 1590	251(4.03) 288(4.10)
IV	$C_{17}H_{16}O_5S$	162[a]	71.4	C 61.44 H 4.85	61.92 4.96	ν_{CO} 1630 1660 1765	244(4.21) 289(4.14) 372(4.03)

recrystallized from *a*) benzene *b*) ether *c*) ethyl acetate–ether *d*) ethyl acetate

Table III. Biphenyl Derivatives

Compound No.	Formula	mp (°C)	Yield (%)	Analysis (%)		IR cm^{-1} (KBr)	UV λ_{max}^{EtOH} nm (log ε)
				Calcd.	Found		
VIa	$C_{15}H_{14}O_2S$	80[a]	85.3	C 69.75 H 5.46	70.06 5.54	ν_{CO} 1639	223(4.38) 260(4.28) 370(3.45)
VIb	$C_{16}H_{16}O_3S$	87[a]	41.7	C 66.66 H 5.59	66.95 5.61	ν_{CO} 1665	255(4.29) 355(3.49)
VIc	$C_{18}H_{18}O_2S$	63[a]	53.7	C 72.46 H 6.08	72.78 6.34	ν_{CO} 1640	224(4.49) 262(4.27) 358(3.46)
VII	$C_{17}H_{18}O_4S$	113[b]	66.6	C 67.99 H 5.37	68.20 5.30	ν_{CO} 1680 1758	255(4.42) 338(3.49)
VIII	$C_{15}H_{14}O_4S$	164[c]	63.5	C 62.06 H 4.86	62.37 4.94	ν_{CO} 1640	225(4.63) 270(3.96) 318(3.51)

recrystallized from *a*) MeOH *b*) MeOH-ether *c*) ether thio group by comparison of its NMR spectrum with that of Vc. In the case of dimethylsulfonium 1-benzoyl-3-acetylallylide (Vd), which would have a *trans* comformation,[1)] no reaction occurred and the starting material was recovered.

These results suggest that intramolecular cyclization occurred between benzoyl and acetyl groups in sulfonium allylide to give easily biphenyl compounds accompanied with the cleavage of C-S bond in dimethylsulfonium or tetramethylenesulfonium.

Further work is in progress on the chemical properties and reactivity of thiabenzene 1-oxide derivatives.

Experimental

All the melting points are uncorrected. Nuclear magnetic resonance (NMR) spectra were measured with a JNM-PS-100 (JEOL) spectrometer using tetramethylsilane as an internal standard. Infrared (IR) spectra were recorded with an IRA-2 (JASCO) spectrophotometer.

Reaction of Ia with NaOEt or NaOMe——a) To a solution of Na (0.14 g, 0.006 mole) dissolved in abs. EtOH (30 ml), 1.02 g (0.003 mole) of Ia was added and the mixture was refluxed for 3 hr. After evaporation of the solvent, H_2O was added to the residue and this was extracted with $CHCl_3$. The extract was dried over Na_2SO_4 and evaporated to dryness. The residue was dissolved in benzene and chromatographed over a silica gel column. The compound obtained from elution with acetone–benzene (1: 10) mixture was recrystallized from AcOEt to give 0.4 g (46.3%) of IIIa, mp 147°. Another compound was obtained from elution with acetone–benzene (3: 10) mixture was recrystallized from benzene to give 0.2 g (36.4%) of IIa, mp 126° (reported[9)] mp 126°). The aqueous layer was acidified with 10% HCl and the precipitated solid was recrystallized from H_2O to afford benzoic acid.

b) To a solution of Na (0.14 g. 0.006 mole) dissolved in abs. MeOH (30 ml), 1.02 g (0.003 mole) of Ia was added and the mixture was refluxed for 3 hr. After evaporation of the solvent, H_2O was added to the residue and this was extracted with $CHCl_3$. The extract was recrystallized from AcOEt to give 0.81 g (93.7%) of IIIa, mp 147°.

Reaction of Ib with NaOEt or NaOMe——a) To a solution of Na (0.18 g, 0.008 mole) dissolved in abs. EtOH (30 ml), 0.98 g (0.0025 mole) of Ib was added and the mixture was refluxed for 3 hr. After the solvent was evaporated, H_2O was added to the residue and this was extracted with $CHCl_3$. The extract was dried over Na_2SO_4 and evaporated to dryness. The residue was recrystallized from ether to give 0.08 g (10%) of IIIc, mp 159°. From the mother liquor, IIb (mp 92°) was obtained in a trace (reported[9)] mp 93°). The aqueous layer was acidified with 10% HCl and extracted with $CHCl_3$. The $CHCl_3$ extract was extracted with 5% Na_2CO_3, several times, the $CHCl_3$ layer was dried over Na_2SO_4 and evaporated to dryness. The residue was recrystallized from benzene to give 0.22 g (30%) of IIIb, mp 147°. The Na_2CO_3 extracts were combined. This alkaline solution was acidified with 10% HCl and extracted with $CHCl_3$. The extract was dried over Na_2SO_4, evaporated to dryness and the residue was recrystallized from AcOEt to give 0.29 g (40%) of IIId, mp 224°.

b) To a solution of 0.98 g (0.0025 mole) of Ib in 10 ml of abs. MeOH, a solution of NaOMe prepared by dissolving 0.18 g (0.008 mole) of Na in 40 ml of abs. MeOH was added, and the resulting solution was refluxed for 3 hr. The same treatment as above afforded 0.05 g (10%) of IIc, mp 120° (from ether), 0.14 g (20%) of IIIb, mp 147° and 0.3 g (40%) of IIId, mp 224°. IIIb and IIId were identified by the mixed melting point determination and IR comparison with samples obtained a) method.

Preparation of IV——A mixture of 0.5 g (0.0017 mole) of IIIb, 10 ml of Ac_2O and 0.5 ml of pyridine was heated at 70°. The reaction mixture was concentrated under a reduced pressure and H_2O was added to the residue. The precipitated solid was recrystallized from benzene to give 0.4 g (71.4%) of IV, mp 162°.

Reaction of IIIc with NaOEt——The reaction of IIIc (0.95 g, 0.003 mole) with NaOEt solution (Na, 0.14 g, 0.006 mole) was carried out in a similar manner as above. The yield of IIId, mp 224°, was 0.7 g (80%). This compound was identified by the mixed melting point determination and IR comparison with an authentic sample of IIId.

Reaction of IIId with conc. H_2SO_4——A mixture of 0.9 g (0.003 mole) of IIId, 1 ml of conc. H_2SO_4, and 20 ml of EtOH was refluxed for 3 hr. After evaporation of the solvent from the reaction mixture, H_2O was added to the residue and the mixture was neutralized with 10% NaOH. The resulting solution was extracted with AcOEt and the extract was dried over Na_2SO_4. The solvent was evaporated and the residue was recrystallized from AcOEt to afford 0.5 g (66.6%) of IIIe, mp 135°.

Reaction of Ic with NaOEt——To a solution of 1.0 g (0.004 mole) of Ic in 10 ml of abs. EtOH, a solution of NaOEt prepared by dissolving 0.18 g (0.008 mole) of Na in 30 ml of abs. EtOH was added and the solution was refluxed for 3 hr. After evaporation of the solvent, H_2O was added to the residue and the solution was extracted with $CHCl_3$. The extract was dried over Na_2SO_4, evaporated to dryness, the residue was dissolved in benzene, and chromatographed over a silica gel column. The compound obtained from elution with acetone–benzene (1: 10) mixture was recrystallized from AcOEt to give 0.9 g (91.8%) of IIIe, mp 135°. This compound was identified by the mixed melting point determination and IR comparison with a sample obtained as in above method.

Reaction of Va with NaOEt——To a solution of Na (0.2 g, 0.01 mole) dissolved in abs. EtOH, 1.45 g (0.005 mole) of Va was added and the mixture was refluxed for 3 hr. After evaporation of the solvent from the reaction mixture, H_2O was added to the residue and this was extracted with $CHCl_3$. The extract was dried over Na_2SO_4, evaporated to dryness, and the residue was recrystallized from MeOH to give 1.1 g (85.3%) of VIa, mp 80°.

Preparation of VII——A mixture of 0.5 g (0.002 mole) of VIa, 10 ml of Ac_2O, and 0.5 ml of pyridine was heated at 70°. The reaction mixture was concentrated under a reduced pressure and H_2O was added to the residue. The precipitated solid was recrystallized from ether to give 0.4 g (66.6%) of VII, mp 113°.

Preparation of VIII——A mixture of 0.5 g (0.002 mole) of VIa, 1 ml of 30% hydrogen peroxide and 20 ml of AcOH was stirred at room temperature for 5 hr. The solvent was evaporated under a reduced pressure and H_2O was added to the residue. The precipitated solid was collected by filtration and recrystallized from MeOH–ether to give 0.35 g (63.5%) of VIII, mp 164°.

Reaction of Vb with NaOEt——To a solution of Na (0.2 g, 0.01 mole) dissolved in abs. EtOH, 1.6 g (0.005 mole) of Vb was added and this was refluxed for 3 hr. After evaporation of the solvent, H_2O was added to the residue and this was extracted with $CHCl_3$. The extract was dried over Na_2SO_4, evaporated to dryness, and the residue was dissolved in benzene and chromatographed over a silica gel column. The compound obtained from elution with benzene was recrystallized from MeOH to give 0.6 g (41.7%) of VIb, mp 87°.

Reaction of Vc with NaOEt——To a solution of Na (0.2 g, 0.01 mole) dissolved in abs. EtOH, 1.58 g (0.005 mole) of Vc was added and this was refluxed for 3 hr. After evaporation of the solvent, H_2O was added to the residue and this was extracted with $CHCl_3$. The extract was dried over Na_2SO_4, evaporated to dryness, and the residue was recrystallized from MeOH to give 0.8 g (53.7%) of Vc, mp 63°.

Acknowlegement The authors are indebted to Mr. K. Masuda for his assistance in the experimental work. Thanks are also due to Mrs. H. Mazume for elementary analyses, to Mr. K. Inada for the measurement of NMR spectra, and to Mr. M. Ohwatari for the measurement of IR and UV spectra.