

NMR study of the naphtho-1,3-dithioles formed from carbamodithioates and 2,3-dichloro-1,4-naphthoquinone

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Reaction of triethylammonium 1,2-ethanedithiolbis(carbamodithioate) with 2,3-dichloro-1,4-naphthoquinone in DMF furnished *N,N'*-ethylenebis(2-iminonaphtho[2,3-*d*][1,3]dithiole-4,9-dione) in 94% yield. Triethylammonium *N*-arylcarbamodithioates reacted with 2,3-dichloro-1,4-naphthoquinone to give 2-(*N*-arylimino)naphtho[2,3-*d*][1,3]dithiole-4,9-diones in good yields. NMR spectroscopic data of the products are discussed.

Keywords: carbamodithioates, dithioles, NMR

Sulfur heterocycles containing benzo- and naphtho-1,3-dithiole moieties have demonstrated anti-angiogenic properties,¹ and are of interest as precursors to functionalised tetrathiofulvalenes,^{2,3} which in turn have a host of applications in molecular electronics.^{4–6} Aly *et al.* have a long-term interest in reactions of thiols and thioamides towards π -acceptors.^{7–10} Here we report the reactions of the carbamodithioates **1** and **5a–e** with 2,3-dichloro-1,4-naphthoquinone (**2**), to give 2-imino-1,3-naphthodithioles.

Results and discussion

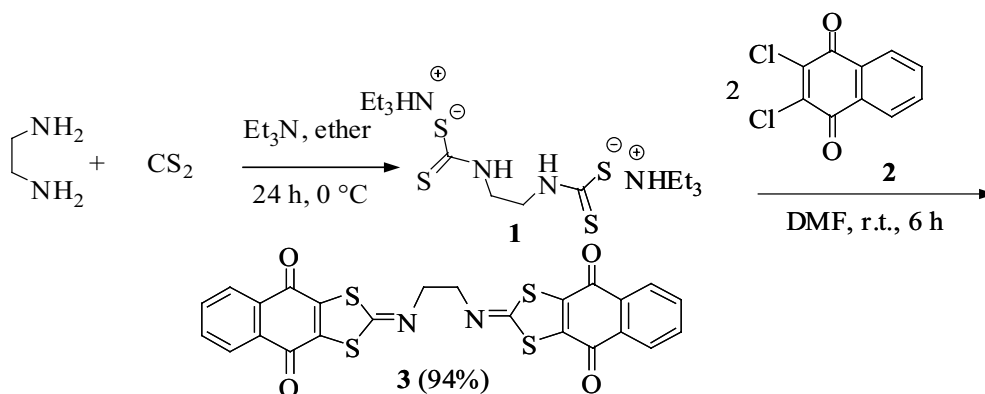
The bis(dithiocarbamate) salt **1**¹¹ was synthesised by adding carbon disulfide to a solution of ethylenediamine and triethylamine. On adding 1 equiv. of **1** to 2 equiv. of 2,3-dichloro-1,4-naphthoquinone (**2**) in DMF, *N,N'*-ethylenebis(2-iminonaphtho[2,3-*d*][1,3]dithiole-4,9-dione) (**3**) was obtained in 6 hours in 94% yield (Scheme 1). The mass spectra of compound **3** showed a molecular ion at m/z 520 (15% of base peak), consistent with the formula $C_{24}H_{12}N_2O_4S_4$, which was confirmed by elemental analysis. The structure assignment of **3** is supported by IR and NMR (¹H, ¹³C) data. The IR spectrum did not show any absorption from C=S, NH, or OH groups, but did show C=O absorption at 1665 cm^{–1}. The ¹H NMR spectrum likewise did not show NH nor OH resonances. The aliphatic CH₂-protons appeared as a broad singlet at δ_H 2.80. The aromatic protons appeared as two 4H multiplets at δ_H = 7.56–7.68 and 7.80–7.92. Salient ¹³C NMR signals correspond to C=O at δ_C = 176.7, C=N at δ_C = 161.0, CO–C–S at δ_C = 139.6, and aliphatic CH₂ at δ_C 54.0.

The carbamodithioates **5a–e** prepared from **4a–e**¹² reacted with compound **2**, to give 2-iminonaphtho[2,3-*d*][1,3]dithiole-4,9-diones **6a–e** (Scheme 2). The IR spectrum did not

reveal any absorption related to C=S, NH and/or OH groups. ¹H NMR spectra of **6a–e** supported the proposed 1,3-dithiole structures, since they did not show any NH- or OH-signals, and the aromatic proton signals in **6a–e** appeared to be symmetrical. In each case, the ¹H integrals require there be one pendant aryl group R and one *o*-phenylene group. This ratio showed that the product arose from one each of **5a–e** as appropriate and **2**. All the correlations are straightforward, and the C=N chemical shifts are 159.8 (**6a**), 159.0 (**6b**), 160.7 (**6c**), 157.4 (**6d**), and 153.3 (**6e**). These chemical shifts require each carbon be a C=N not a C=S. Carbonyl signals are also present. The other carbon resonances in the naphthoquinone part structures support their near-symmetry, and are closely similar in all five compounds.

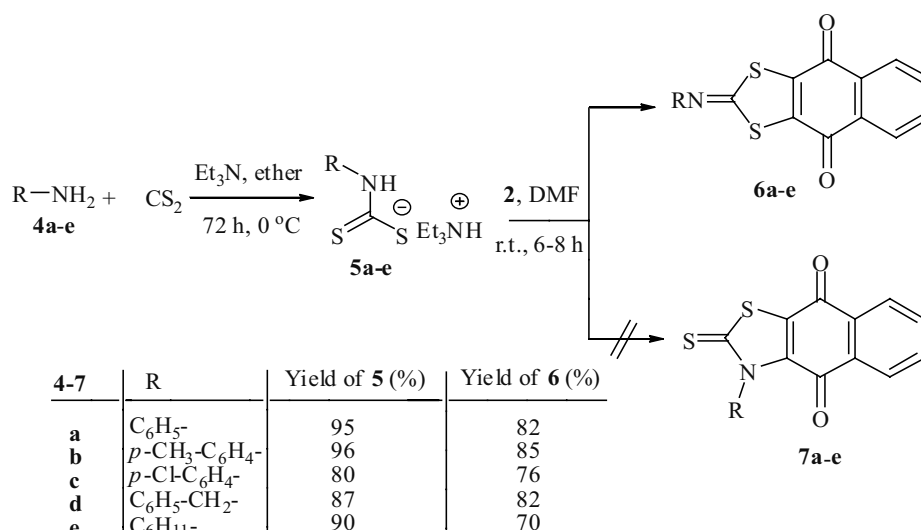
In **6d** and **6e**, HMBC correlations were observed between the azomethine carbon and the aliphatic protons α to nitrogen, establishing the connection between the C=N and the benzyl and cyclohexyl groups respectively. The NMR properties are much more consistent with structures **6a–e** than with the alternative naphthothiazoles **7a–e**.

The NMR spectra of **6e** (Table 1) exemplify those of the whole series. The ¹H NMR spectrum contains one CHN proton at δ_H = 2.91, and four aromatic protons. This ratio showed that the product arose from one each of **5e** and **2**. Neither **6e** nor the alternative benzothiazole product **7e** has a σ plane, so either should theoretically give 15 ¹³C lines (the cyclohexyl ring has local symmetry). Fourteen lines were observed, so one pair of nonequivalent carbons is co-resonant. The aromatic ¹H pattern resembles an AA'XX' pattern and is so analysed;¹³ this analysis yields values for all the coupling constants in the system ($J_{AA'}$, J_{AX} , $J_{AX'}$, and $J_{XX'}$).¹³ Since the two sides of the *o*-phenylene ring are nonequivalent, the pattern is technically an ABXY, with A and B being



Scheme 1 Synthesis of *N,N'*-ethylenebis(2-iminonaphtho[2,3-*d*][1,3]dithiole-4,9-dione).

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Scheme 2 Reactions of carbamodithioates **5a-e** with **2**: synthesis of naphtho-1,3-dithioles **6a-e**

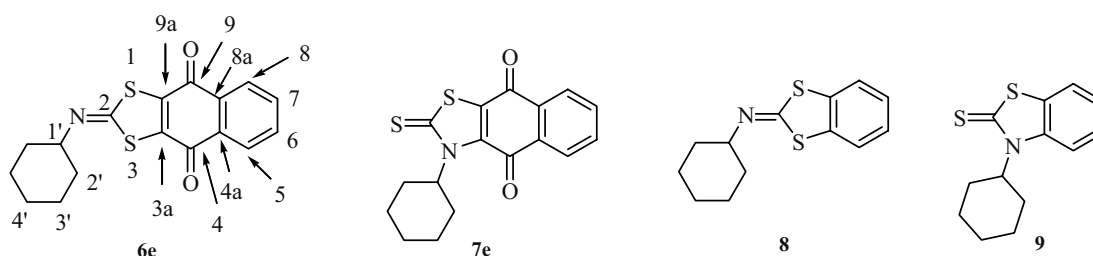


Fig. 1

co-resonant, and X and Y also co-resonant. The ¹H-¹H coupling constants require that δ_H 8.12 be H-6,7 and δ_H 7.76 be H-5,8. These protons give HMQC correlation to carbons at δ_C 127.11 (C-6,7; co-resonant) and δ_C 134.21, 134.16 (C-5,8). The assignments are supported by the observation of HMBC correlation between C-6,7 and H-6,7 together with the absence of HMBC correlation between C-5,8 and H-5,8. These would be correlations between one of the two carbons and the *other* hydrogen, *e.g.* between C-6 and H-7: two bonds in the C/H-6,7 pair but four bonds in the C/H-5,8 pair. HMBC correlations are much more commonly observed over two

bonds than over four. The non-protonated carbons at δ_C = 132.1, 132.0 give HMBC correlation with C-5,8 and H-6,7; these carbons are assigned as C-4a,8a. The almost co-resonant carbons at δ_C 176.2, 175.8 and δ_C 143.6, 143.3 give no HMBC correlations; they are assigned as C-4,9 and C-3a,9a respectively. The downfield *sp*³ carbon at δ_C 69.5 is assigned as C-1'; the attached H at δ_H 2.91 gives HMBC correlation with the remaining *sp*² carbon at δ_C 153.3, which is assigned as the C=N. In the alternative naphthothiazole structure **7e**, H-1' would be three bonds from C-3a, hence might give HMBC correlation with this carbon; that this correlation is

Table 1 NMR spectroscopic data of compound **6e**

¹ H NMR (CDCl ₃)		COSY	Assignment
8.12 (ABXY, J _{AX} = 7.6, J _{AB} = 7.1, J _{AY} = 1.4; 2H)		7.76	H-6,7
7.76 (ABXY, J _{AX} = 7.6, J _{AY} = 1.4, J _{XY} = 0.0; 2H)		8.12	H-5,8
2.91 (tt, J = 9.8, 3.8; 1H)		1.82, 1.46	H-1'
1.82 (m; 4H)		2.91, 1.67, 1.46, 1.29	H-2',3'
1.67 (m; 1H)		1.82, 1.29	H-4'
1.46 (m; 2H)		2.91, 1.87, 1.46, 1.29	H-2'
1.29 (m; 3H)		1.82, 1.67, 1.46, 1.29	H-3',4'
¹³ C NMR (CDCl ₃)		HMBC	Assignment
176.2, 175.8			C-4,9
153.3		2.91	C=N
143.6, 143.3			C-3a,9a
134.21, 134.16	7.76	8.12	C-5,8
132.1, 132.0		8.12, 7.76	C-4a,8a
127.1		8.128, 12, 7.76	C-6,7
69.5		2.911, 82	C-1'
32.2		1.82, 1.462, 91, 1.29	C-2'
25.44		1.671, 29	C-4'
24.50		1.82, 1.291, 82, 1.46	C-3'

absent does not exclude structure **7e**, but is more supportive of **6e** (Scheme 2). Further evidence for structure **6e** comes from comparison of experimental and calculated (CHEMNMR: increment method) ^{13}C chemical shifts to those of model compounds. First, the experimental azomethine δ_{C} for **6e** (153.3) is much closer to the calculated C=N values for itself (162.6) and compound **8** (δ_{C} 162.8), than to the C=S values for **9¹⁴** (exp. 189.0, calcd 193.9; Fig. 1). Second, the carbon resonances on the side positions of the benzene ring differ by several ppm in **9¹⁴** in **8** and in **6e**, these chemical shifts are calculated to coincide, and in the experimental spectrum of **6e**, they are within 0.08 ppm. Correlations in compounds **6a–d** are equally straightforward. Therefore, compounds **6a–e** are assigned as naphtho-1,3-dithioles (Scheme 2). The *o*-phenylene ^1H NMR signals of **6a–d** cannot be fully solved as AA'XX' patterns, apparently because the chemical shifts of H-6,7 differ just enough to distort the AA' part of the pattern; the assignments of these signals are based on their 2D correlations and by analogy with **6e**.

Conclusion

Carbamodithioates react with 2,3-dichloro-1,4-naphthoquinone to give naphtho-1,3-dithioles and *not* naphthothiazoles.

Experimental

Melting points are uncorrected. ^1H NMR and ^{13}C NMR spectra were measured on Bruker AM-400 or AV-400 spectrometers (400.13 MHz for ^1H and 100.6 MHz for ^{13}C); chemical shifts are in ppm from TMS (δ), and coupling constants are in Hz. The AV-400 was purchased with assistance from the National Science Foundation (CHE 03-42251). For preparative thin layer chromatography (PLC), glass plates (20 \times 48 cm) were covered with slurry of silica gel Merck PF₂₅₄ and air-dried using the solvents listed for development. Zones are detected by quenching of indicator fluorescence upon exposure to 254 nm UV light. Elemental analyses were carried in Assiut Microanalysis Centre of Assiut University. Mass spectroscopy was performed with a Finnigan Mat 8430 spectrometer at 70 eV Institute of Organic Chemistry, TU-Braunschweig, Germany. IR spectra were run on a Shimadzu 470 spectrometer using KBr pellets.

Starting materials

The bis(dithiocarbamate) salt **1** was prepared according to ref. 11, and the carbamodithioates **5a–e** were prepared according to ref. 12.

Reactions of **1** with **2**

A mixture of **1** (0.414 g, 1 mmol) with **2** (0.454 g, 2 mmol) in DMF (50 mL) was stirred at room temperature 6 h. The precipitate formed, **3**, was washed with cold ethanol (50 mL) and then dissolved in acetone (20 mL). The solution was subjected to preparative TLC using toluene: ethyl acetate (1 : 1, silica gel). The zone of compound **3** was extracted and the product **3** was recrystallised.

N,N'-Ethylenebis(2-iminonaphtho[2,3-d][1,3]dithiole-4,9-dione) (**3**): Greenish white colourless crystals (0.52 g, 94%), m.p. >360°C (ethyl acetate). ^1H NMR (DMSO- d_6): 8.12–8.04 (m, 2H, Ar-H), 7.76–7.60 (m, 6H, Ar-H), 3.20 (s, 4H, CH₂). ^{13}C NMR (100.6 MHz, DMSO- d_6): δ_{C} = 178.7 (4C=O), 162.0 (2C=N), 140.0 (4 CO–C–S), 132.0 (4 CO–C–Ar), 130.8 (Ar-4CH), 128.0 (Ar-4CH), 50.3 (2CH₂). IR (KBr): ν_{max} = 3100–3000 (w, Ar-CH), 2900–2840 (m, aliph.-CH), 1665 (s, CO), 1625 (m, C=N), 1595 (m, C=C) cm^{-1} . λ_{max} (CH₃CN, lg ϵ , nm): 370 (3.6). MS (EI): m/z (%) = 520 [M^+] (15), 286 (14), 272 (18), 260 (100), 228 (22), 224 (20), 152 (24), 128 (34), 77 (24), 67 (22). C₂₄H₁₂N₂O₄S₄ (520.62): Calcd C, 55.37; H, 2.32; N, 5.38; S, 24.64. Found: C, 55.20; H, 2.34; N, 5.30; S, 24.60.

Reactions of **5a–e** with **2**

A mixture of **5a–e** (1 mmol) with **2** (0.227 g, 1 mmol) in DMF (50 mL) was stirred at room temperature for 6–8 h. The solvent was removed under vacuum and the residue was subjected to preparative TLC using silica gel, toluene: ethyl acetate 10:1. The products **6a–e** were isolated and recrystallised from the stated solvents.

2-(Phenylimino)naphtho[2,3-d][1,3]dithiole-4,9-dione (**6a**): Red crystals (0.26 g, 82%), m.p. 213–215°C (ethanol). ^1H NMR (CDCl₃) 8.12 (m, 2H; H-6,7), 7.76 (m, 2H; H-5,8), 7.43 ("t", J = 7.9, 2H; H-3'), 7.22 (t, J = 7.5, 1H; H-4'), 7.03 (dd, J = 7.4, 1.0, 2H; H-2'). ^{13}C NMR (CDCl₃) 176.2, 175.9 (C-4,9), 159.9 (C=N), 150.8 (C-1'), 143.5, 143.3 (C-3a,9a), 134.3 (C-5,8), 132.1, 132.0 (C-4a,8a), 129.9

(C-3'), 127.2 (C-6,7), 125.9 (C-4'), 119.5 (C-2'). IR (KBr): ν_{max} 3105–3008 (w, Ar-CH), 1665 (s, CO), 1610 (s, C=N), 1590 (s, C=C) cm^{-1} . λ_{max} (CH₃CN, lg ϵ , nm): 400 (4.0). MS (EI): m/z (%) = 323 [M^+] (93), 220 (20), 188 (34), 160 (22), 135 (100), 104 (37), 76 (38). C₁₇H₉NO₂S₂ (323.39): Calcd C, 63.14; H, 2.81; N, 4.33; S, 19.83. Found: C, 63.00; H, 2.75; N, 4.20; S, 20.00%.

2-(*p*-Tolylimino)naphtho[2,3-d][1,3]dithiole-4,9-dione (**6b**): Red crystals (0.29 g, 85%), m.p. 184°C (ethanol). ^1H NMR (CDCl₃) 8.11 (m, 2H; H-6,7), 7.76 (m, 2H; H-5,8), 7.22 (d, J = 8.1, 2H; H-3'), 6.93 (d, J = 8.2, 1H; H-2'), 2.37 (s, 3H; CH₃). ^{13}C NMR (CDCl₃) 176.2, 175.8 (C-4,9), 159.0 (C=N), 148.3 (C-4'), 143.4, 143.2 (C-3a,9a), 135.7 (C-1'), 134.30, 134.26 (C-5,8), 132.1, 132.0 (C-4a,8a), 130.4 (C-3'), 127.2 (C-6,7), 119.5 (C-2'), 21.1 (CH₃). IR (KBr): ν_{max} = 3086–3008 (w, Ar-CH), 2972–2860 (m, aliph-CH), 1660 (s, CO), 1610 (s, C=N), 1590 (s, C=C) cm^{-1} . λ_{max} (CH₃CN, lg ϵ , nm): 406 (4.1). MS (EI): m/z (%) = 337 [M^+] (100), 322 (27), 220 (16), 188 (4), 149 (56), 117 (19), 104 (38), 91 (36), 76 (15), 65 (26). C₁₈H₁₁NO₂S₂ (337.42): Calcd C, 64.07; H, 3.29; N, 4.15; S, 19.01. Found: C, 64.00; H, 3.20; N, 4.07; S, 18.92%.

2-(4-Chlorophenylimino)naphtho[2,3-d][1,3]dithiole-4,9-dione (**6c**): Reddish blue crystals (0.27 g, 76%), m.p. 218°C (ethanol). ^1H NMR (CDCl₃) 8.12 (m, 2H; H-6,7), 7.78 (m, 2H; H-5,8), 7.39 (d, J = 8.2, 2H; H-3'), 6.97 (d, J = 8.2, 2H; H-2'). ^{13}C NMR (CDCl₃) 176.1, 175.7 (C-4,9), 160.7 (C=N), 149.1 (C-1'), 143.6, 143.1 (C-3a,9a), 134.41, 134.38 (C-5,8), 132.0, 131.9 (C-4a,8a), 131.2 (C-4'), 130.0 (C-3'), 127.2 (C-6,7), 121.1 (C-2'). IR (KBr): ν_{max} = 3090–3010 (w, Ar-CH), 1660 (s, CO), 1612 (s, C=N), 1580 (m, C=C) cm^{-1} . λ_{max} (CH₃CN, lg ϵ , nm): 408 (3.6). MS (EI): m/z (%) = 357 [M^+] (100), 322 (16), 220 (20), 188 (20), 169 (71), 104 (32), 76 (26). C₁₇H₈ClNO₂S₂ (357.84): Calcd C, 57.06; H, 2.25; Cl, 9.91; N, 3.91; S, 17.92. Found: C, 57.22; H, 2.20; Cl, 10.08; N, 3.80; S, 17.80%.

2-(Benzylimino)naphtho[2,3-d][1,3]dithiole-4,9-dione (**6d**): Pale red crystals (0.28 g, 82%), m.p. 176–178°C (ethanol). ^1H NMR (CDCl₃) 8.14 (m, 2H; H-6,7), 7.77 (m, 2H; H-5,8), 7.37 (m, 4H; H-2,3'), 7.30 (m, 1H; H-4'), 4.44 (s, 2H; CH₂). ^{13}C NMR (CDCl₃) 176.3, 175.7 (C-4,9), 157.4 (C=N), 144.2, 143.1 (C-3a,9a), 137.4 (C-1'), 134.34, 134.25 (C-5,8), 132.1, 132.0 (C-4a,8a), 128.7, 127.8 (C-2',3'), 127.5 (C-4'), 127.2 (C-6,7), 62.6 (CH₂). IR (KBr): ν_{max} = 3090–3000 (w, Ar-CH), 2970–2840 (m, aliph-CH), 1662 (s, CO), 1615 (m, C=N), 1595 (m, C=C), 1450 (m, CH₂) cm^{-1} . λ_{max} (CH₃CN, lg ϵ , nm): 392 (3.7). MS (EI): m/z (%) = 337 [M^+] (58), 332 (18), 188 (26), 149 (15), 117 (19), 104 (32), 91 (100), 76 (30), 65 (22). C₁₈H₁₁NO₂S₂ (337.42): Calcd C, 64.07; H, 3.29; N, 4.15; S, 19.01. Found: C, 64.20; H, 3.20; N, 4.12; S, 18.89%.

2-(Cyclohexylimino)naphtho[2,3-d][1,3]dithiole-4,9-dione (**6e**): Yellow crystals (0.23 g, 70%), m.p. 170–171°C (ethanol). NMR (see Table 1). IR (KBr): ν_{max} = 3098–3002 (w, Ar-CH), 2990–2820 (m, aliph-CH), 1665 (s, CO), 1610 (s, C=N), 1595 (s, C=C), 1455 (w, CH₂) cm^{-1} . λ_{max} (CH₃CN, lg ϵ , nm): 380 (3.5). MS (EI): m/z (%) = 329 [M^+] (100), 296 (60), 286 (54), 247 (30), 220 (31), 189 (33), 141 (36), 104 (42), 76 (28), 67 (14). C₁₇H₁₅NO₂S₂ (329.44): Calcd C, 61.98; H, 4.59; N, 4.25; S, 19.47. Found: C, 61.78; H, 4.50; N, 4.20; S, 19.30%.

Received 21 August 2009; accepted 21 October 2009

Paper 09/0753 doi: 10.3184/030823409X12561978806846

Published online: 17 November 2009

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