Activated Carbonyl Species for the Preparation of *ortho*-Acylarylsydnones

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ortho-Acylarylsydnones can be prepared in moderate to good yield by the action of nucleophiles upon suitable activated carbonyl species.

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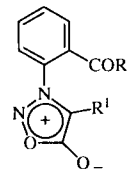
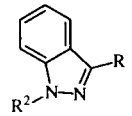
Much of our recent work has involved the use of *o*-acylarylsydnones and related carbonyl containing species (*cf.* **1** and **2**) [1]. Using such compounds we have shown that acid-induced cleavage can lead to indazole derivatives (*cf.* **7** or **8**) [1], or treatment with bases (*e.g.* from **3** and hydrazine, methylamine or ammonia) affords the novel sydnoindole **9** [1a]. However, further pursuit of these pathways has been hindered by the relative inaccessibility of the starting compounds **1**; most being available only in several steps from the corresponding *o*-substituted aniline derivative [2]. Obviously, advantages would accrue if such species could be prepared in one or two steps from a single sydnone precursor. This report outlines our efforts to utilize either active esters (prepared from the carboxylic acid **4**) or the trihaloacetyl species **5** or **6** as the single precursor.

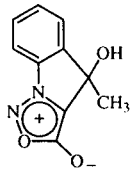
For the former, we utilized initially a protocol involving treatment of **4** with dicyclohexylcarbodiimide in tetrahydrofuran followed by an amine nucleophile. With the two amines tried, *viz.* benzylamine and propylamine, the corresponding amides **11e** and **11f** were formed, albeit in 53% and 30% yield, respectively. Given the low product yields it was elected to prepare a potentially more reactive ester **10** from the reaction of **4** with *N*-hydroxysuccinimide in the presence of dicyclohexylcarbodiimide. The desired product **10** was obtained in 71% yield and then was subjected to reaction with various nucleophiles, including amines, alkoxides, hydrides and organolithium species (Scheme 1) (Table 1). Thus, moderate yields (34-64%) of the corresponding amides **11a-h** were obtained by reaction with the corresponding amines. The active ester **10** did not react with alcohols but ester products **11i,j** did result in 40% and 66% yield, respectively, upon use of the



1, R = various, R^1 = H
2, R = various, R^1 = Br
3, R = Me, R^1 = H
4, R = OH, R^1 = H
5, R = CBr_3, R^1 = H
6, R = CCl_3, R^1 = H



7, R = various, R^2 = H
8, R = various, R^2 = COBr



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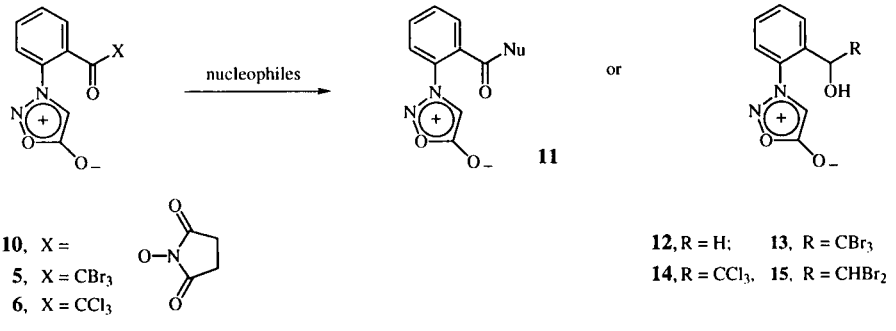
Scheme 1



10, X =
5, X = CBr_3
6, X = CCl_3

11

12, R = H; **13**, R = CBr_3
14, R = CCl_3, **15**, R = $CHBr_2$

Table 1

Reactions of Active Ester **10** or Trihaloacetyl Species **5** and **6** with Nucleophiles

Entry	Nucleophile	Product **11**, Nu=	% Yield from **10**	% Yield from **5**	% Yield from **6**	Reference
1	H_2NNH_2	**a**, $NHNH_2$	53	--	60	3
2	H_2NNHPh	**b**, NHNHPh	34	--	--	--
3	NH_4OH	**c**, NH_2	64	--	58	3
4	H_2NMe	**d**, NHMe	50	92	90	4
5	H_2NBn	**e**, NHBn	41	--	86	--
6	H_2NPr	**f**, NHPr	63	--	--	--
7	H_2N*i*-Pr	**g**, NH*i*-Pr	61	--	--	--
8	H_2N*s*-Bu	**h**, NH*s*-Bu	51	--	--	--
9	NaOEt	**i**, OEt	40	95	80	--
10	NaOMe	**j**, OMe	66	68	--	3
11	$NaBH_4$/MeOH	**j**, OMe	25	--	--	3
12	$NaCNBH_3$	**i**, OEt	23	--	--	--
13	MeLi, PhLi, *n*-BuLi	**k**, $CHBr_2$	--	59, 39, 42	--	--
14	MeLi, PhLi	**l**, $CHCl_2$	--	--	79, 37	--
15	$NaBH_4$/THF	**14**	--	--	62	--
16	$NaBH_4$/THF	**15**	--	39	--	--

corresponding sodium alkoxides. Attempted displacement by hydride was unsuccessful. Thus, with sodium borohydride in methanol, only the methyl ester **11j** was obtained in 25% yield and the ethyl ester **11i** resulted in 23% yield from treatment with sodium cyanoborohydride in ethanol. Some reduction of **10** did occur by heating with sodium borohydride in ethanol but none of the expected aldehyde **11** (Nu=H) resulted, and only the primary alcohol **12** was obtained in 10% yield. Complex, inseparable mixtures resulted upon treatment of **10** with methyllithium, butyllithium or phenyllithium.

Following Atkins' procedure (*viz.* tribromo- or trichloroacetic acid in dimethyl sulfoxide followed by acetic anhydride) [5] we were able to prepare the trihaloacetyl species **5** and **6** from the known sydnone aldehyde **11** (Nu=H) in 75% and 49% yield, respectively. The aldehyde had been prepared previously from ester **11j** by reduction to the primary alcohol **12** followed by oxidation with pyridinium dichromate [6], however, the yields always were unsatisfactory, ranging from 35-40% for the 2 steps. We were able to improve the yield considerably by subjecting **11j** to treatment with diisobutylaluminum hydride (DIBAL); the aldehyde was obtained in 67% yield. The conversion of **11** (Nu=H) to **5** or **6** was sensitive to the amount of water present in the dimethyl sulfoxide, thus, the greater the amount, the greater the yield of the alcohol by-products **13** and **14**. The best results (75% and 49% yields of **5** and **6**, respectively) were obtained in anhydrous dimethyl sulfoxide under an atmosphere of dry nitrogen gas. With pure samples in hand, **5** or **6** were subjected to a variety of nucleophiles, including amine derivatives, alkoxides, hydrides and organolithium species, (Scheme 1) (Table 1). Thus, moderate to good yields (58-92%) of the corresponding amide derivatives **11a,c-e** resulted from treatment of **5** or **6** with amines and good yields (68-95%) of the sydnone esters **11i-j** were obtained by treatment of **5** with sodium ethoxide or sodium methoxide, respectively. More unusual results were forthcoming from reactions with organolithium species or sodium borohydride. Thus, exposure of **5** or **6** to organolithium reagents, in an attempt to prepare the corresponding ketones, gave moderate to good yields of the corresponding dihaloacetylsydnones **11k** or **11l**, respectively, presumably *via* metal-halogen exchange to form enolates which resist further nucleophilic attack. A similar process took place in the reaction of **5** with sodium borohydride, where the dibromo alcohol **15** was obtained in low yield. With **6**, only ketone to alcohol reduction (to form **14**) was observed under these conditions. The different outcomes are due, presumably, to the greater polarizability and, hence, greater susceptibility of the bromine atom to attack by nucleophiles.

The identities of the sydnone products **11-15** were established by comparison with authentic products or *via* satisfactory microanalyses, the presence of both sydnone CH and C=O stretching absorptions in their infrared spectra (approximately 3120 and 1750 cm^{-1}, respectively) and sydnone ring proton absorption in their proton nmr spectra (δ 6.6-7.8). In addition, in their carbon nmr spectra, the C-4 position appeared at ~97-99 ppm, in line with known values (95.1) [5] for sydnones unsubstituted at the 4-position.

Overall, we have shown that the activated ester **10** and the trihaloacetylsydnones **5** and **6** can be employed for the preparation of a variety of *o*-acyl arylsydnones and we intend to explore further the utility of this process, especially with other organometallic species.

EXPERIMENTAL

All melting points were determined on a Mel-Temp apparatus and are uncorrected. Infrared spectra (potassium bromide) were measured on a Perkin Elmer 1600 Fourier transform (FT) instrument and nuclear magnetic resonance spectra (^1H and ^{13}C) on an IBM NR/200 FTNMR at 200 MHz or 50 MHz, respectively, with tetramethylsilane as the internal standard, chemical shifts reported in ppm (δ). Combustion analyses were performed by Midwest Microlab, Indianapolis, Indiana.

Reaction of 3-(2-Carboxyphenyl)sydnone (**4**) with Amines and Dicyclohexylcarbodiimide.

General Procedure.

To a stirred solution of **4** (0.25 g, 1.21 mmoles) in tetrahydrofuran (20 mL) was added dicyclohexylcarbodiimide (DCC) (0.25 g, 1.21 mmoles) followed by the appropriate amine (0.5 mL). After 12 hours at room temperature, the mixture was filtered and the filtrate was evaporated *in vacuo*. The residual solid was recrystallized from dichloromethane/hexane.

3-[2-(*N*-Benzylaminocarbonyl)phenyl]sydnone (**11e**).

Using benzylamine in the general procedure gave the title compound as a colorless solid, 0.194 g (54%); mp 155-156°; ir: 3326 (N-H stretching), 3148 (sydnone C-H stretching), 1731 (sydnone C=O stretching), 1639 (amide C=O stretching), 1542, 1226 and 941 cm^{-1}; ^1H-nmr (deuteriochloroform): δ 7.48 (m, 9H), 6.62 (s, 1H), 6.21 (s br, 1H), 4.59 (m, 2H); ^{13}C-nmr (deuteriodimethyl sulfoxide): 168.3, 164.7, 138.8, 132.6, 132.4, 132.1, 131.4, 129.2, 128.3, 127.1, 126.9, 126.1, 98.4, 42.6 ppm.

Anal. Calcd. for $C_{16}H_{13}N_3O_3$: C, 65.08; H, 4.44; N, 14.23. Found: C, 64.96; H, 4.63; N, 14.14.

3-[2-(*N*-propylaminocarbonyl)phenyl]sydnone (**11f**).

Using propylamine in the general procedure gave the title compound as a colorless solid, 0.088 g (29%), mp 145-146°; ir: 3322 (N-H stretching), 3148 (sydnone C-H stretching), 2968, 2931, 2867 (alkyl C-H stretching), 1732 (sydnone C=O stretching), 1643 (amide C=O stretching), 1551, 1227, 1145 and 762 cm^{-1}; ^1H-nmr (deuteriochloroform): δ 7.64 (m, 4H), 6.66 (s, 1H), 5.98 (s br, 1H), 3.32 (m, 2H, $NHCH_2$),1.55 (m, 2H), 0.93 (t, 3H); ^{13}C-nmr (deuterioacetone): 169.1, 165.4, 134.4, 133.0, 131.9, 129.8, 126.7, 108.6, 98.3, 41.9, 23.2, 11.6 ppm.

Anal. Calcd. for $C_{12}H_{13}N_3O_3$: C, 58.29; H, 5.30; N, 16.99; O, 19.41. Found: C, 58.16; H, 5.34; N, 16.67; O, 19.44.

3-[2-(*N*-(Succinimido)oxycarbonyl)phenyl]sydnone (**10**).

To a stirred solution of 3-(2-carboxyphenyl)sydnone (**4**) (2.0 g, 9.7 mmoles) in tetrahydrofuran (100 mL) was added *N*-hydroxysuccinimide (1.2 g, 9.7 mmoles) followed by dicyclohexylcarbodiimide (2.0 g, 9.7 mmoles). After 12 hours, the mixture was filtered and the filtrate was evaporated *in vacuo* to yield a yellow powder which was dissolved in dichloromethane (200 mL) and washed with water (2 x 200 mL). The organic layer was dried (sodium sulfate), concentrated *in vacuo* and recrystallized from dichloromethane/hexane to yield colorless crystals of the title compound, 2.1 g (71%), mp 152-154°; ir: 3146 (sydnone C-H stretching), 2949 (aliphatic C-H stretching), 1727 (sydnone C=O stretching), 1435, 1291, 940 and 764 cm^{-1}; ^1H-nmr (deuteriochloroform): δ 8.34 (dd, 1H), 7.9 (m, 2H), 7.70 (dd, 1H), 6.65 (s, 1H), 2.89 (s, 4H); ^{13}C-nmr (deuteriochloroform): 170.1, 169.0, 160.1, 136.7, 135.4, 134.0, 132.9, 128.9, 122.9, 99.1, 26.3 ppm.

Anal. Calcd. for $C_{13}H_9N_3O_6 \cdot 0.5\ H_2O$: C, 50.00; H, 3.21; N, 13.46. Found: C, 50.24; H, 2.95; N, 13.34.

Reaction of 3-[2-(*N*-(Succinimido)oxycarbonyl)phenyl]sydnone (**10**) with Nitrogen Nucleophiles.

General Procedure.

To compound **10** (0.20 g, 0.66 mmole) in tetrahydrofuran (10 mL) was added the appropriate amine (10 equivalents). After stirring at room temperature, or with heating, as appropriate, the solvent was removed *in vacuo*. The resultant solid or oil was digested with water (30 mL) and extracted into dichloromethane (2 x 50 mL). The combined extracts were dried (sodium sulfate) and concentrated *in vacuo*. The resultant amides were isolated by trituration or recrystallization.

3-[2-(Hydrazinocarbonyl)phenyl]sydnone (**11a**).

Using hydrazine hydrate in the general procedure at room temperature gave, after 1 hour, and recrystallization from hot methanol, tan crystals of the title compound, 0.079 g (53%), identical (melting point, infrared) to an authentic sample [3].

3-[2-(*N'*-Phenyl-*N*-hydrazinocarbonyl)phenyl]sydnone (**11b**).

Using phenylhydrazine in the general procedure at room temperature gave, after 1 hour and trituration with ether (2 x 20 mL), the title compound as a white powder, 0.066 g (34%), mp 160-162°; ir: 3332 (N-H stretching), 3149 (sydnone C-H stretching), 1734 (sydnone C=O stretching), 1638 (amide C=O stretching), 1600, 1495, 1361, 1226, 1174, 940, 760 and 692 cm^{-1}; ^1H-nmr (deuteriodimethyl sulfoxide): δ 6.86 (s, 1H), 6.81 (m, 9H).

Anal. Calcd. for $C_{15}H_{12}N_4O_3$: C, 60.81; H, 4.08; N, 18.91. Found: C, 61.01; H, 4.20; N, 18.54.

3-[2-(Aminocarbonyl)phenyl]sydnone (**11c**).

Using ammonium hydroxide in the general procedure at 110° gave, after 4 hours and recrystallization from hot methanol, colorless crystals of the title compound, 0.088 g (64%), identical (melting point, infrared) to an authentic sample [3].

3-[2-(*N*-Methylaminocarbonyl)phenyl]sydnone (**11d**).

Using methylamine in the general procedure at 65° gave, after 2 hours, trituration with ether (10 mL) and recrystallization from hot methanol, colorless crystals of the title compound, 0.072 g (50%), identical (melting point, infrared) to an authentic sample [4].

3-[2-(*N*-Benzylaminocarbonyl)phenyl]sydnone (**11e**).

Using benzylamine in the general procedure gave, after 1 hour, and recrystallization from dichloromethane/hexane, colorless crystals of the title compound, 0.079 g (40.5%), identical (melting point, infrared) to an authentic sample.

3-[2-(*N*-Propylaminocarbonyl)]phenylsydnone (**11f**).

Using propylamine in the general procedure gave, after 30 minutes, and trituration with diethyl ether (20 mL), colorless crystals of the title compound, 0.103 g (63%), identical (melting point, infrared) to an authentic sample.

3-[2-(*N*-Isopropylaminocarbonyl)]phenylsydnone (**11g**).

Using isopropylamine in the general procedure gave, after 30 minutes, and trituration with diethyl ether (20 mL), colorless

crystals of the title compound, 0.099 g (61%), mp 126-127°; ir: 3315 (N-H stretching), 3145 (sydnone C-H stretching), 2985 (alkyl C-H stretching), 1730 (sydnone C=O stretching), 1637 (amide C=O stretching), 1542, 1228 and 761 cm^{-1}; ^{1}H-nmr (deuteriochloroform): δ 7.54 (m, 4H), 6.65 (s, 1H), 5.69 (s br, 1H), 4.12 (m, 1H), 1.36 (d, 3H), 1.20 (d, 3H); ^{13}C-nmr (deuterioacetone): 170.0, 164.7, 134.6, 133.4, 133.0, 131.8, 129.8, 126.3, 98.3, 42.5, 22.3 ppm.

Anal. Calcd. for $C_{12}H_{13}N_3O_3$: C, 58.28; H, 5.30; N, 16.99. Found: C, 58.51; H, 5.40; N, 16.51.

3-[2-(*N-sec*-Butylaminocarbonyl)]phenylsydnone (**11h**).

Using *sec*-butylamine in the general procedure gave, after 12 hours, and trituration with diethyl ether (20 mL), colorless crystals of the title compound as a colorless solid, 0.088 g (51%), mp 90-92°; ir: 3318 (N-H stretching), 3136 (sydnone C-H stretching), 2970 (alkyl C-H stretching), 1728 (sydnone C=O stretching), 1626 (amide C=O stretching), 1400, 1228, 939 and 762 cm^{-1}; ^{1}H-nmr (deuteriochloroform): δ 7.63 (m, 4H), 6.65 (s, 1H), 5.73 (s br, 1H), 3.98 (m, 1H), 1.44 (m, 2H), 1.16 (d, 3H), 0.96 (t, 3H); ^{13}C-nmr (deuterioacetone): 169.0, 165.0, 134.7, 133.3, 133.0, 131.7, 129.7, 126.5, 108.5, 98.2, 47.8, 20.2, 10.7 ppm.

Anal. Calcd. for $C_{13}H_{15}N_3O_3$: C, 59.76; H, 5.79; N, 16.08; O, 18.37. Found: C, 59.65; H, 5.82; N, 16.02; O, 18.44.

3-[2-(Ethoxycarbonyl)phenyl]sydnone (**11i**).

To a stirred solution of **10** (0.10 g, 0.33 mmole) in ethyl alcohol (10 mL) was added sodium ethoxide (0.10 g, 1.5 mmoles). After 12 hours the ethanol was evaporated and the residual solid was treated with water (25 mL) and extracted into methylene chloride (2 x 25 mL). The combined extracts were dried (sodium sulfate), concentrated *in vacuo* and the residue crystallized from dichloromethane/hexane to yield the title compound as colorless crystals, 0.031 g (40%), mp 89-91°, ir: 3135 (sydnone C-H stretching), 3074 (aromatic C-H stretching), 2988, 2941 (aliphatic C-H stretching), 1748 (sydnone C=O stretching), 1717 (C=O stretching), 1616, 1279, 1079 and 764 cm^{-1}; ^{1}H-nmr (deuteriochloroform): δ 7.9 (m, 4H), 6.6 (s, 1H), 4.2 (q, 2H), 1.3 (t, 3H).

Anal. Calcd. for $C_{11}H_{10}N_2O_4$: C, 56.41; H, 4.27; N, 11.97. Found: C, 56.21; H, 4.14; N, 11.93.

3-[2-(Methoxycarbonyl)phenyl]sydnone (**11j**).

To a stirred solution of **10** (0.20 g 0.66 mmole) in methyl alcohol (20 mL) was added sodium methoxide (0.20 g, 4.2 mmoles). After 12 hours, the methanol was evaporated and the residue was triturated with water (50 mL) and extracted into dichloromethane (2 x 50 mL). The combined extracts were dried (sodium sulfate), concentrated *in vacuo* and the residue triturated with ethyl ether to yield the title compound, 0.096 g (66%), identical (melting point, infrared) to an authentic sample [3].

3-[2-(Formyl)phenyl]sydnone (**11**, Nu=H) *via* Reduction of **11j**.

To 3-[2-(methoxycarbonyl)phenyl]sydnone (**11j**) (2.34 g, 10.64 mmoles) in anhydrous dichloromethane (30 mL) at -78° was added diisobutylaluminum hydride (1.0*M* in dichloromethane) (15 mL, 15 mmoles) slowly with stirring under an atmosphere of dry nitrogen. After 1 hour, the reaction was quenched by the slow addition of 5% hydrochloric acid (5 mL). The mixture was allowed to warm to room temperature, poured into water and dichloromethane (600 mL, 1:1) and filtered. The aqueous layer was extracted with dichloromethane (3 x 50 mL) and the combined extracts were reduced in volume to about 50 mL. The resultant solution was dried (magnesium sulfate), filtered, reduced *in vacuo* and flash columned (silica gel, 100% dichloromethane gradient to 2% acetone/dichloromethane) to yield an orange oil. Trituration with ether and crystallization from dichloromethane/hexane afforded the title compound as a pale tan solid, 1.36 g (67%), identical (melting point, infrared) to an authentic sample [6].

3-[2-(Tribromomethylcarbonyl)phenyl]sydnone (**5**) [7].

To a stirred solution of 3-(2-formylphenyl)sydnone (**11**, Nu=H) (1.167 g, 6.1 mmoles) in anhydrous dimethyl sulfoxide (5 mL) was added dry tribromoacetic acid (2.722 g, 9.2 mmoles) under an atmosphere of dry nitrogen. After 4.5 hours, acetic anhydride (15 mL, 159.5 mmoles) was added and, after a further 22 hours, the mixture was poured into water (60 mL) at 5°. The solid was collected by filtration, dissolved in dichloromethane (20 mL), dried (magnesium sulfate), filtered and reduced *in vacuo*. Crystallization from dichloromethane/hexane afforded the title compound as colorless needles, 2.03 g (75.5%), mp 133.5-135°; ir: 3136 (sydnone C-H stretching), 1737 (sydnone C=O stretching), 1719 (C=O stretching), 1606, 1442, 1211 and 778 cm^{-1}; ^{1}H-nmr (deuteriodimethyl sulfoxide): δ 8.0 (m, 4H), 7.7 (s, 1H).

Anal. Calcd. for $C_{10}H_5Br_3N_2O_3$: C, 27.21; H, 1.13; N, 6.35. Found: C, 27.45; H, 1.33; N, 6.70.

3-[2-(Trichloromethylcarbonyl)phenyl]sydnone (**6**) [7].

To a stirred solution of **11**, Nu=H (0.332 g, 1.75 mmoles) in anhydrous dimethyl sulfoxide (5 mL) was added dry trichloroacetic acid (0.444 g, 2.72 mmoles) under an atmosphere of dry nitrogen. After 4 hours, acetic anhydride (4 mL, 42.5 mmoles) was added and, after a further 22 hours, the mixture was poured into water (40 mL) at 5°. The solid was removed by filtration, the filtrate was extracted with dichloromethane (3 x 20 mL), the combined extracts were added to the solid, washed with water (10 mL), dried (magnesium sulfate), filtered and reduced *in vacuo* to an orange oil. Column chromatography (silica gel, dichloromethane/hexane (2:1) gradient to dichloromethane) followed by trituration of the resultant solid with ethyl ether/hexane (4:1) afforded the title compound as colorless crystals, 0.263 g (49%), mp 112-113°, ir: 3134 (sydnone C-H stretching), 1745, 1734 (C=O stretching), 1607, 1438, 1214 and 1088 cm^{-1}; ^{1}H-nmr (deuteriodimethyl sulfoxide): δ 8.2 (m, 4H), 7.75 (s, 1H).

Anal. Calcd. for $C_{10}H_5Cl_3N_2O_3$: C, 39.06; H, 1.64; N, 9.11. Found: C, 39.32; H, 1.76; N, 9.05.

Nucleophilic Substitution Reactions with the Trihalocarbonylphenylsydnones **5** or **6**.

A. With Nitrogen Nucleophiles.

General Procedure.

To the sydnone **5** or **6** (0.50 mmole) in tetrahydrofuran (4 mL) was added the appropriate amine (2 equivalents). After stirring at room temperature, or with heating, as appropriate, the solvent was removed *in vacuo*. The resultant solid or oil was triturated or recrystallized to afford the corresponding amide.

3-[2-(Hydrazinocarbonyl)phenyl]sydnone (**11a**).

Using compound **6** and hydrazine monohydrate in the general procedure at room temperature gave, after 1 hour, and recrystallization from hot methanol, the title compound as pale yellow crystals, 0.068 g (60%), identical (melting point, infrared) to an authentic sample [3].

3-[2-(Aminocarbonyl)phenyl]sydnone (**11c**).

Using compound **6** and ammonium hydroxide in the general procedure gave, after 1 hour at 110°, trituration with ethyl ether and recrystallization from hot methanol, the title compound as an off-white solid, 0.059 g (58%), identical (melting point, infrared) to an authentic sample [3].

3-[2-(*N*-Methylaminocarbonyl)phenyl]sydnone (**11d**).

Using compound **6** and methylamine (40%) in the general procedure at room temperature gave, after 1 hour, trituration with ethyl ether/hexane (3:1) and recrystallization from hot methanol, the title compound as colorless crystals, 0.096 g (90%), identical (melting point, infrared) to an authentic sample [4].

3-[2-(*N*-Methylaminocarbonyl)phenyl]sydnone (**11d**) from **5**.

Using compound **5** and methylamine (40%) in the general procedure at room temperature gave, after 1 hour, trituration with ethyl ether/hexane (3:1) and recrystallization from hot methanol, the title compound as colorless crystals, 0.10 g (92%), identical (melting point, infrared) to an authentic sample [4].

3-[2-(*N*-Benzylaminocarbonyl)phenyl]sydnone (**11e**).

Using compound **6** and benzylamine in the general procedure at room temperature gave, after 1 hour, trituration with ethyl ether and recrystallization from hot methanol, the title compound as colorless crystals, 0.127 g (86%), identical (melting point, infrared) to an authentic sample.

B. With Alkoxides.

Reaction of 3-[2-(Tribromomethylcarbonyl)phenyl]sydnone (**5**) with Sodium Methoxide.

To compound **5** (0.446 g, 1.01 mmoles) in tetrahydrofuran (8 mL) and methanol (4 mL) was added sodium methoxide (0.118 g, 2.20 mmoles) with stirring at room temperature. After 70 hours, evaporation of the solvent *in vacuo* left a solid which was digested with dichloromethane (20 mL) and filtered. The filtrate was dried (magnesium sulfate) and reduced *in vacuo*. Column chromatography (silica gel, dichloromethane/hexane 4:1) yielded an orange oil which on trituration with ethyl ether afforded 3-[2-(methoxycarbonyl)phenyl]sydnone (**11j**) as a tan solid, 0.153 g (68%), identical (melting point, infrared) to an authentic sample [3].

Reaction of **5** with Sodium Ethoxide to Form 3-[2-(Ethoxycarbonyl)phenyl]sydnone (**11i**).

To 3-[2-(tribromomethylcarbonyl)phenyl]sydnone (**5**) (0.113 g, 0.257 mmole) in tetrahydrofuran (4 mL) and ethanol (3 mL) was added sodium ethoxide (0.039 g, 0.580 mmole) with stirring at room temperature. After 1 hour, more sodium ethoxide (0.042 g, 0.620 mmole) was added and, after 20 hours, the reaction mixture was filtered, the resultant solid was rinsed with dichloromethane (10 mL), and the combined organics were evaporated *in vacuo*. The residue was dissolved in dichloromethane (20 mL), dried (magnesium sulfate), filtered, and reduced *in vacuo* to an orange oil which crystallized from dichloromethane/hexane as pale tan crystals of the title compound, 0.057 g (95%), identical (melting point, infrared) to a previously prepared sample.

Reaction of 3-[2-(Trichloromethylcarbonyl)phenyl]sydnone (**6**) with Sodium Ethoxide to Form **11i**.

To compound **6** (0.097 g, 0.32 mmole) in tetrahydrofuran (4 mL) and ethanol (4 mL) was added sodium ethoxide (0.049 g, 0.72 mmole) with stirring at room temperature. After 1 hour, the mixture was filtered, the solid was rinsed with dichloromethane (5 mL) and the combined extracts were dried (magnesium sulfate), filtered, and reduced *in vacuo* to an oily solid. Recrystallization from dichloromethane/hexane afforded the title compound as tan crystals, 0.059 g (80%), identical (melting point, infrared) to a previously prepared sample.

C. With Alkyl and Aryllithium Reagents.

General Procedure.

To the sydnone **5** or **6** (0.26 mmole) in anhydrous tetrahydrofuran (10 mL) at -78° was added the alkyl or aryllithium (2.2 equivalents) slowly with stirring. After 1 hour, the reaction was quenched using 5% hydrochloric acid solution (5 mL) and then was allowed to warm to room temperature. The mixture was added to water (10 mL), extracted with dichloromethane (3 x 25 mL), and the combined organics were dried (magnesium sulfate), filtered, and reduced *in vacuo* to a red oil. Column chromatography (silica gel, dichloromethane), followed by trituration with ethyl ether afforded a yellow solid which recrystallized from dichloromethane/hexane as colorless crystals of 3-[2-(dibromomethylcarbonyl)phenyl]sydnone (**11k**) or 3-[2-(dichloromethylcarbonyl)phenyl]sydnone (**11l**).

3-[2-(Dibromomethylcarbonyl)phenyl]sydnone (**11k**) Using *n*-Butyllithium.

Using compound **5** and *n*-butyllithium in the general procedure produced the title compound, 0.039 g (42%), mp 132-133°; ir: 3155 (sydnone C-H stretching), 1757 (sydnone C=O stretching), 1737 (C=O stretching), 1438, 1290, 1189, 989, 943 and 787 cm^{-1}; ^{1}H-nmr (deuteriodimethyl sulfoxide): δ 7.94 (m, 4H), 6.96 (s, 1H, C*H*Br_2), 6.69 (s, 1H); ^{13}C-nmr (deuteriodimethyl sulfoxide): 185.1, 167.8, 133.3, 132.3, 132.1, 130.0, 128.7, 125.8, 96.8, 40.9 ppm.

Anal. Calcd. for $C_{10}H_6Br_2N_2O_3$: C, 33.18; H, 1.67; N, 7.74. Found: C, 32.97; H, 1.62; N, 7.45.

3-[2-(Dibromomethylcarbonyl)phenyl]sydnone (**11k**) Using Methyllithium.

Using compound **5** and methyllithium in the general procedure gave the title compound, 0.055 g (59%), identical (melting point, infrared) to an authentic sample.

3-[2-(Dibromomethylcarbonyl)phenyl]sydnone (**11k**) Using Phenyllithium.

Using compound **5** and phenyllithium in the general procedure gave the title compound, 0.038 g (39%), identical (melting point, infrared) to an authentic sample.

3-[2-(Dichloromethylcarbonyl)phenyl]sydnone (**11l**) Using Phenyllithium.

Using compound **6** and phenyllithium in the general procedure gave the title compound, 0.027 g (37%), mp 110-112°; ir (potassium bromide): 3161 (sydnone C-H stretching), 3012 (aromatic C-H stretching), 1750 (sydnone C=O stretching), 1715 (C=O stretching), 1440, 1214, 1194, 1074, 946, 812, and 678

cm^{-1}; ^{1}H-nmr (deuteriodimethyl sulfoxide): δ 8.10 (m, 4H), 7.76 (s, 1H, C*H*Cl_2), 7.65 (s, 1H); ^{13}C-nmr (deuteriodimethyl sulfoxide): 185.9, 168.1, 134.5, 132.8, 132.6, 130.7, 128.7, 127.1, 98.4, 69.8 ppm.

Anal. Calcd. for $C_{10}H_6Cl_2N_2O_3$: C, 43.98; H, 2.21; N, 10.26. Found: C, 43.59; H, 2.10; N, 10.02.

3-[2-(Dichloromethylcarbonyl)phenyl]sydnone (**11l**) Using Methyllithium.

Using compound **6** and methyllithium in the general procedure gave the title compound, 0.056 g (79%), identical (melting point, infrared) to an authentic sample.

D. With Sodium Borohydride.

Using 3-[2-(Tribromomethylcarbonyl)phenyl]sydnone (**5**).

To compound **5** (0.221 g, 0.50 mmole) in tetrahydrofuran (4 mL) was added sodium borohydride (0.233 g, 6.2 mmoles) with stirring at room temperature. After 24 hours, the insoluble solid was removed by filtration and rinsed with dichloromethane (3 x 5 mL). The combined organics were washed with water (10 mL), dried (magnesium sulfate), filtered and reduced *in vacuo* to a yellow oil. Trituration with ethyl ether, followed by recrystallization from hot ethanol, yielded 3-[2-(1-hydroxy-2,2-dibromoethyl)-phenyl]sydnone (**15**) as colorless crystals, 0.071 g (39%), mp 114-115°; ir: 3465 (O-H stretching), 3129 (sydnone C-H stretching), 1732 (sydnone C=O stretching), 1440, 1358, 1182, 1093, 940, 776 and 745 cm^{-1}; ^{1}H-nmr (deuteriodimethyl sulfoxide): δ 7.80 (m, 4H), 7.57 (s, 1H), 6.95 (d, 1H, C*H*Br_2), 6.24 (d, O*H*), 4.66 (t, 1H); ^{13}C-nmr (deuteriodimethyl sulfoxide): 166.1, 135.6, 132.6, 132.2, 129.8, 129.0, 125.8, 99.4, 72.4, 51.3 ppm.

Anal. Calcd. for $C_{10}H_8Br_2N_2O_3$: C, 33.00; H, 2.21; N, 7.70. Found: C, 33.18; H, 2.24; N, 7.58.

Using 3-[2-(Trichloromethylcarbonyl)phenyl]sydnone (**6**).

To compound **6** (0.097 g, 0.32 mmole) in tetrahydrofuran (4 mL) was added sodium borohydride (0.111 g, 2.94 mmoles) in portions with stirring at room temperature. After 1 hour, the insoluble solid was removed by filtration and rinsed with dichloromethane (3 x 5 mL). The combined organics were dried (magnesium sulfate), filtered, and reduced *in vacuo* to an orange oil. Trituration with ethyl ether then ethyl ether/hexane (4:1), followed by recrystallization from benzene, afforded 3-[2-(1-hydroxy-2,2,2-trichloroethyl)phenyl]sydnone (**14**) as a colorless solid, 0.061 g (62%), mp 174-176°; ir: 3288 (O-H stretching), 3142 (sydnone C-H stretching), 1740, 1715 (sydnone C=O stretching), 1358, 1090, 948, 821 and 766 cm^{-1}; ^{1}H-nmr (deuteriodimethyl sulfoxide): δ 7.93 (m, 4H), 7.64 (s, 1H), 5.44 (d, 1H).

Anal. Calcd. for $C_{10}H_7Cl_3N_2O_3$: C, 38.77; H, 2.26; N, 9.05. Found: C, 39.01; H, 2.13; N, 8.98.

REFERENCES AND NOTES

[1a] C. R. Gelvin and K. Turnbull, *Helv. Chim. Acta*, **75**, 1931 (1992); [b] J. A. Marx and K. Turnbull, *Tetrahedron Letters*, **34**, 239 (1993).

[2] S. J. Hodson and K. Turnbull, *J. Heterocyclic Chem.*, **22**, 1223 (1985).

[3] P. N. Preston and K. Turnbull, *J. Chem. Soc., Perkin Trans. 1*, 1229 (1977).

[4] K. Turnbull, T. L. Blackburn and D. T. Esterline, *J. Heterocyclic Chem.*, **27**, 1259 (1990).

[5] S. P. Wang, C. N. Kuo, S. Ma and M.-Y. Yeh, *Spectroscopy Letters*, **26**, 431 (1993).

[6] J. D. Lowe and K. Turnbull, *J. Heterocyclic Chem.*, **23**, 125 (1986).

[7] P. J. Atkins, V. Gold and W. Wassef, *J. Chem. Soc., Perkin Trans. 2*, 1247 (1984).