Preparation of Adamantyl Sulfides with [Bis(1-adamantanecarboxy)iodo]arenes and Disulfides

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Irradiation of [bis(1-adamantanecarboxy)iodo]arenes with a high-pressure mercury lamp in the presence of disulfides gives the corresponding adamantyl sulfides in high yields. This reaction proceeds via the radical decarboxylation of [bis(1-adamantanecarboxy)iodo]arenes followed by S_H2 reaction of the carbon radical on the disulfide.

Recently, (diacyloxyiodo)arenes have been used as oxidants, carbon–carbon bond forming reagents, and radical precursors.[1] [Bis(1-adamantanecarboxy)iodo]arenes, easily prepared by the reaction of (diacetoxyiodo)arenes with 1-adamantanecarboxylic acid, are powerful carbon radical precursors[2] for carbon–carbon bond formations. However, the use of (diacyloxyiodo)arenes for the formation of sulfides has never been studied. Adamantyl sulfides and selenides have been of interest in photochemical studies because of their specific photobehavior.[3] As a part of our study on the radical reactivity of (diacyloxyiodo)arenes, we report here on the conversion of [bis(1-adamantanecarboxy)iodo]arenes to the corresponding adamantyl sulfides.

Radical substitution reactions at hetero atoms via an S_H2 mechanism have been studied by Russell using alkyl mercury halides.[4] However, to our knowledge the adamantyl sulfides have not been synthesized by this method to date. The synthesis of adamantyl sulfides via an ionic pathway is difficult because the adamantyl group retards S_N2 reaction at its tertiary carbon atom; synthetic methods have been limited.[3,5] Alternatively, single electron transfer (SET) reaction of haloadamantane with thiolate anion[6] and S_H2 reaction of *N*-adamantanecarboxy-2-thiopyridone with tri(phenylthio)phosphite[7] gave the corresponding adamantyl sulfides in moderate yields. Our present method is more practical because of the neutral reaction conditions, simple experimental operation, and good yields of the reaction products.

A mixture of [bis(1-adamantanecarboxy)iodo]benzene (**1**) and disulfide **2** was irradiated with a high-pressure mercury lamp for three hours in dichloromethane at 30 °C to give the corresponding adamantyl sulfides. Various disulfides were used, and the results are shown in Table 1. Yields depended on the type of disulfide; the yield of **3** was best when the molar ratio of **1** to **2** was 1.0 : 0.5–0.7 with diaryl disulfides, and 1.0 : 1.0–1.2 with dialkyl disulfides, respectively. Moreover, even with dimesityl disulfide and bis(2,4,6-triisopropylphenyl) disulfide which have sterically hindered sulfur atoms, the corresponding sulfides were obtained in moderate to good yields.

The reaction conditions used gave rise partly to thioarylation of diaryl disulfides via a radical pathway when diaryl disulfide was used, while such a side reaction did not occur with dialkyl disulfides.

Table 1. Conversion to Adamantyl Sulfide

$$\underset{\mathbf{1}}{\mathrm{PhI(OCOAd)_2}} + \underset{\mathbf{2}}{\mathrm{RSSR}} \xrightarrow[\mathrm{CH_2Cl_2}]{\mathrm{Hg\text{-}hv}} \underset{\mathbf{3}}{\mathrm{AdSR}} + \mathrm{PhI} + \mathrm{AdCOOH}$$

Entry	R	Ratio (**1** : **2**)	Product	Yield[a] (%)
1	4-Methoxyphenyl	1 : 0.7	**3a**	79
2	4-Methylphenyl	1 : 0.5	**3b**	74
3	Phenyl	1 : 0.5	**3c**	71[b]
4	4-Chlorophenyl	1 : 0.5	**3d**	61
5	2,4,6-Trimethylphenyl	1 : 0.7	**3e**	72
6	2,4,6-Triisopropylphenyl	1 : 0.7	**3f**	23
7	Butyl	1 : 1.0	**3g**	71
8	Dodecyl	1 : 1.2	**3h**	80

[a] Yields were calculated based on compound **1**.
[b] Recovery of iodobenzene and 1-adamantanecarboxylic acid was 82 % and 86 %, respectively.
Ad = 1-adamantyl

Table 2. Reactivity of [Bis(1-adamantanecarboxy)iodo]arenes to Ditolyl Disulfide

$$\underset{\mathbf{1}}{\mathrm{ArI(OCOAd)_2}} + \underset{\mathbf{2}}{\mathrm{TolSSTol}} \xrightarrow[\mathrm{CH_2Cl_2}]{\mathrm{Hg\text{-}hv}} \underset{\mathbf{3}}{\mathrm{AdSTol}}$$

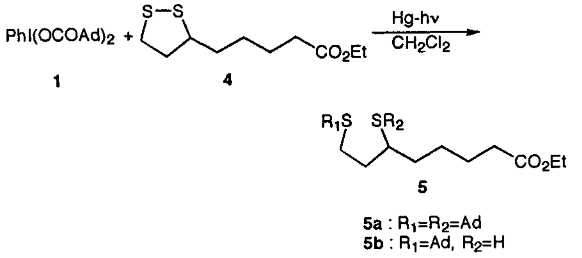
Entry	Ar[a]	Yield (%)
1	4-Methoxyphenyl	77
2	4-Methylphenyl	70
3	Phenyl	74
4	4-Chlorophenyl	69
5	4-Nitrophenyl	16
6	Pentafluorophenyl	0

[a] The molar ratio of **1** : **2** was 1 : 0.5 (mmol).

The reactivity of various [bis(1-adamantanecarboxy)iodo]arenes with ditolyl disulfide was then studied (Table 2). The introduction of strong electron-withdrawing groups, such as nitro and perfluoro, to the aromatic ring in [bis(1-adamantanecarboxy)iodo]arene remarkably retarded the S_H2 reaction, probably because the bond energy between the oxgen and iodine atoms in compound **1** was increased. Consequently, oxidation of the disulfide by compound **1** occurred faster than the S_H2 reaction.

In the reaction with a cyclic disulfide such as ethyl lipotate (**4**), bisadamantylsulfide **5a** and mercaptoadamantylsulfide **5b** were obtained. Each sulfide was selectively formed by the control of the ratio of [bis(1-adamantanecarboxy)iodo]benzene and ethyl lipotate (**4**). When diphenyl and bis(4-methoxyphenyl) diselenides were used instead of disulfides, the corresponding adamantyl selenides were obtained in good yields (adamantyl phenyl selenide 61 %, adamantyl 4-methoxyphenyl selenide 49 %), and in the same way, with the use of other (diacyloxyiodo)arenes such as [bis(cyclohexanecarboxy)iodo]benzene and [bis(pentadecanecarboxy)iodo]benzene, the corresponding sulfides were obtained in moderate yields (cyclohexyl dodecyl sulfide 39 %, pentadecyl dodecyl sulfide 25 %

Table 3. Selective Formations of Bissulfide and Mercaptosulfide from Ethyl Lipotate

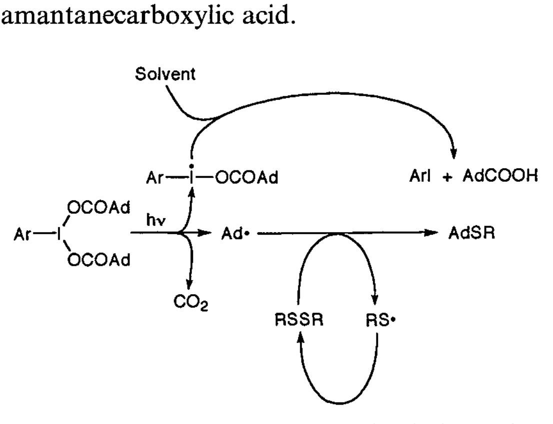


Entry	Ratio (**1** : **4**)	Yields (%)^a **5a**	Yields (%)^a **5b**	Ratio (**5a** : **5b**)
1	4 : 1	54	trace	mainly **5a**
2	2 : 1	32	13	2.5 : 1
3	1 : 1	12	46	0.3 : 1
4	0.5 : 1	trace	41	mainly **5b**

[a] Yields were calculated based on compound **4**.

with didodecyl disulfide). A plausible reaction mechanism is shown in Scheme 1.

The adamantyl radical is first generated via decarboxylation of [bis(1-adamantanecarboxy)iodo]arenes by irradiation with a high-pressure mercury lamp.[2] Subsequent attack by the adamantyl radical on the sulfur atom of the disulfide produces the adamantyl sulfide and thiyl radical. The thiyl radical recombines to form disulfide and it reacts with adamantyl radical again. The divalent iodine radical intermediate probably abstracts a hydrogen atom from the solvent to give the iodoarene and 1-adamantanecarboxylic acid.



Scheme 1. Plausible Mechanism of Photochemical Reaction

In conclusion, this method is useful for the synthesis of adamantyl sulfides and selenides under photochemical conditions in view of the neutral reaction conditions and simple experimental operation.

The disulfides were prepared by the iodine oxidation of thiols. Most of the thiols were commercially available. A few thiols were prepared from the corresponding sulfonyl chloride by lithium aluminium hydride reduction. [Bis(1-adamantanecarboxy)iodo]arenes were prepared by the acyloxy exchange reaction[8] of (diacetoxyiodo)arenes and 1-adamantanecarboxylic acid. Satisfactory microanalyses were obtained for compounds **3b**, **3d**, **3e**, **3h** and **5b**: C ± 0.33; H ± 0.31; **3a**: C ± 0.55, H ± 0.22. Satisfactory HRMS were obtained for compounds **3a–b**, **3d–e**, **3g–h** and **5a**: $m/z = \pm 0.0005$ amu.

Synthesis of Adamantyl Sulfides; General Procedure:

The reaction was carried out with a molar ratio of disulfide/[bis(1-adamantanecarboxy)iodo]arene of 0.5–1.2 : 1.0. A solution of disulfide and [bis(1-adamantanecarboxy)iodo]arene in dry CH_2Cl_2 (5 mL) was irradiated with a high-pressure mercury lamp (400 W) for 3 h at 30 °C. The resulting solution was quenched with sat. aq sodium hydrogen carbonate (5 mL). The organic layer was extracted with CH_2Cl_2 (3 × 20 mL) and dried (Na_2SO_4). After removal of the solvent under reduced pressure the residual oil was purified by preparative TLC on silica gel using hexane or hexane: EtOAc (12 : 1 ~ 4 : 1) as eluent. Yields are given in Tables 1 and 3.

1-Adamantyl 4-Methoxyphenyl Sulfide (**3a**): mp 65.0–66.0 °C.
IR (KBr): ν = 2860, 1580, 1480, 1340, 1240, 835, 800 cm^{-1}.
^{1}H NMR (270 MHz, $CDCl_3$): δ = 1.64–2.14 (15 H, m, adamantyl), 3.82 (3 H, s, CH_3), 6.84 (2 H, d, J = 8.9 Hz, Ar), 7.40 (2 H, d, J = 8.9 Hz, Ar).

1-Adamantyl 4-Methylphenyl Sulfide (**3b**): mp 87.5–88.0 °C.
IR (KBr): ν = 2820, 1425, 1290, 1170, 1095, 1030, 800, 680 cm^{-1}.
^{1}H NMR (270 MHz, $CDCl_3$): δ = 1.50–2.00 (15 H, m, adamantyl), 2.36 (3 H, s, CH_3), 7.12 (2 H, d, J = 7.9 Hz, Ar), 7.38 (2 H, d, J = 7.9 Hz, Ar).

1-Adamantyl Phenyl Sulfide (**3c**): mp 72.0–72.5 °C (lit.[6] mp 72–73 °C).

1-Adamantyl 4-Chlorophenyl Sulfide (**3d**): mp 119–120 °C.
IR (KBr): ν = 2880, 1460, 1290, 1090, 1010, 840, 820, 750 cm^{-1}.
^{1}H NMR (270 MHz, $CDCl_3$): δ = 1.55–2.00 (15 H, m, adamantyl), 7.28 (2 H, d, J = 8.6 Hz, Ar), 7.42 (2 H, d, J = 8.6 Hz, Ar).

1-Adamantyl 2,4,6-Trimethylphenyl Sulfide (**3e**): oil.
IR (neat): ν = 2850, 1590, 1100, 850 cm^{-1}.
^{1}H NMR (270 MHz, $CDCl_3$): δ = 1.62–2.00 (15 H, m, adamantyl), 2.27 (3 H, s, CH_3), 2.54 (6 H, s, CH_3), 6.95 (2 H, s, Ar).

1-Adamantyl 2,4,6-Triisopropylphenyl Sulfide (**3f**): mp 92–93 °C.
IR (KBr): ν = 2895, 1595, 1460, 1300, 1110, 890, 775 cm^{-1}.
^{1}H NMR (270 MHz, $CDCl_3$): δ = 1.10–1.35 (18 H, m, CH_3), 1.60–2.00 (15 H, m, adamantyl), 2.88 (1 H, septet, J = 0.74 Hz, CH), 4.10 (2 H, septet, J = 0.74 Hz, CH), 7.00 (2 H, s, Ar).

1-Adamantyl Butyl Sulfide (**3g**): oil.
IR (neat): ν = 2870, 2650, 1440, 1100, 1045, 980 cm^{-1}.
^{1}H NMR (270 MHz, $CDCl_3$): δ = 0.91 (3 H, t, J = 7.3 Hz, CH_3), 1.37–1.60 (4 H, m, CH_2CH_2), 1.69–2.01 (15 H, m, adamantyl), 2.51 (2 H, t, J = 7.4 Hz, SCH_2).

1-Adamantyl Dodecyl Sulfide (**3h**): oil.
IR (neat): ν = 2870, 2650, 1440, 1100, 1045, 980, 720 cm^{-1}.
^{1}H NMR (270 MHz, $CDCl_3$): δ = 0.90 (3 H, t, J = 0.88 Hz, CH_3), 1.18–1.60 (20 H, m, CH_2), 1.68–2.05 (15 H, m, adamantyl), 2.49 (2 H, t, J = 0.95 Hz, SCH_2).

Ethyl 6,8-Bis(1-adamantylthio)octanoate (**5a**): oil.
IR (neat): ν = 2870, 2650, 1720, 1440, 920 cm^{-1}.
^{1}H NMR (270 MHz, $CDCl_3$): δ = 1.26 (3 H, t, J = 7.3 Hz, CH_3), 1.45–2.15 (38 H, m, —CH_2–, adamantyl), 2.31 (2 H, t, J = 7.6 Hz, —CH_2–CO), 2.63 (2 H, t, J = 7.4 Hz, SCH_2), 2.77 (1 H, m, -S–CH–), 4.12 (2 H, q, J = 7.2 Hz, OCH_2).

Ethyl 6-Mercapt-8-(1-adamantylthio)octanoate (**5b**): oil.
IR (neat): ν = 2870, 2650, 1725, 1440, 1040, 920, 740 cm^{-1}.
^{1}H NMR (270 MHz, $CDCl_3$): δ = 1.26 (3 H, t, J = 7.3 Hz, CH_3), 1.48–2.05 (24 H, m, CH_2, adamantyl, SH), 2.31 (2 H, t, J = 7.8 Hz, CH_2CO), 2.64 (2 H, t, J = 7.4 Hz, SCH_2), 2.77 (1 H, m, SCH), 4.12 (2 H, q, J = 7.2 Hz, OCH_2).
MS (Fab): m/z = 369 $(M–H)^+$.

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