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A New Electrochemical Method of Preparation of Unsymmetrical Disulfides

Quang Tho Do[a], Driss Elothmani[a], Georges Le Guillanton[a] * and Jacques Simonet[b]

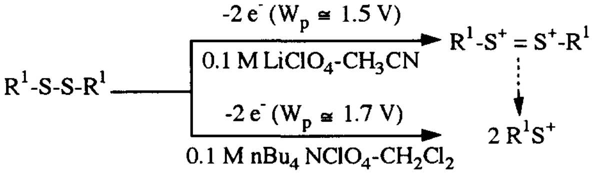
Laboratoire d'Électrochimie Organique,
[a]Université Catholique de l'Ouest and CNRS, BP 808, 49008 ANGERS Cedex 01 (France).
[b]Université de Rennes 1 and CNRS, 35042 RENNES (France).

Abstract: A new method is described for the preparation of unsymmetrical disulfides by reaction of the electrogenerated sulfenium cation R^1-S^+ with thiols or disulfides. © 1997 Elsevier Science Ltd.

Unsymmetrical disulfides can be prepared by reaction of sulfenamides[1], thiophthalimides[2], sulfenylthiocarbonates[3], alkyl(aryl) sulfanylhalides[4] or dithioperoxyesters[5] with thiols.

A novel and very simple method is described, where electrophilic species prepared by anodic oxidation of symmetrical disulfides are reacted with thiols or other disulfides.

We have recently reported that the electrochemical oxidation at a platinum electrode of organic disulfides affords the transient electrophilic cation R^1-S^+, according to the scheme below. This mechanism was supported by UV spectroscopy.[6]



In acetonitrile, dicationic species R^1-S^+ = S^+-R^1 were found to be predominant but can evolve towards the monocation R^1-S^+. In dichloromethane, the formation of the sulfenium cation R^1-S^+ was assumed to result from the cleavage of the S-S bond because the applied potential was higher. This cation can react with various nucleophiles such as thiols to give the expected unsymmetrical disulfides :

$$R^1S^+ + R^2SH \longrightarrow R^1\text{-S-S-}R^2 + H^+$$

In the present preliminary note, R^1-S^+ was prepared from diphenyl disulfide, dibenzyl disulfide and dimethyl disulfide by electrochemical oxidation at potentials of 1.80 V, 1.55 V and 1.50 V vs SCE, respectively.

A small amount of the symmetrical disulfide R^2-S-S-R^2 (about 10-15%) was sometimes characterized as by-product because R^1-S^+ can also oxidize the thiol R^2-SH.

As expected unsymmetrical disulfides are also oxidizable in the same range as potential of the symmetrical ones, they are prepared in a two step process as described below. First, a macroscale electrolysis is carried out in an H-type cell equipped with a platinum foil (area 16 cm^2) as working electrode, a carbon rod as counter-electrode and a saturated calomel electrode (SCE) as reference. A symmetrical disulfide (72 mM) dissolved in a solution of 0.1 M nBu_4NClO_4 - CH_2Cl_2 is electrolysed for about twenty hours, at the working potential mentioned above, until two moles of electron per mole of disulfide are consumed. The solution of R^1S^+ is stable for several days.[6] At the end of the electrolysis, 72 mM of the suitable thiol R^2-SH are added and stirred for several hours. After a suitable treatment[6b], the crude product was purified by column chromatography on silica gel (60 H, Merck) using the mixture cyclohexane/ethyl acetate (9 : 1, v : v) as eluent. The products, which are known in the literature, were identified by IR, ^1H-NMR and mass spectrometry.[7] Yields are in the range 60-90 % as indicated in Table I for some examples.

Table I - Preparation of unsymmetrical disulfides from thiols

Thiol	R^1-S^+	Product^7		Isolated yield (%)
$CH_3CH_2CH_2$-SH	PhS^+	$CH_3CH_2CH_2$-S-S-Ph	**1**	68
tert-C_4H_9-SH		tert-C_4H_9-S-S-Ph	**2**	90
Ph-CH_2-SH		Ph-CH_2-S-S-Ph	**3**	72
Ph-SH	Ph-CH_2-S^+	Ph-S-S-CH_2-Ph	**3**	61
tert-C_4H_9-SH		tert-C_4H_9-S-S-CH_2-Ph	**4**	58
Ph-CH_2-SH	CH_3-S^+	Ph-CH_2-S-S-CH_3	**5**	72

It has also been observed that R^1S^+ can react directly with a symmetrical disulfide R^2-S-S-R^2 which is a good nucleophile.

$$2\,R^1S^+ + R^2\text{-S-S-}R^2 \longrightarrow 2\,R^1\text{-S-S-}R^2$$

The experimental conditions are the same as mentioned above except that the disulfide R^2-S-S-R^2 is introduced after electrolysis, instead of the thiol and yields of unsymmetrical disulfides obtained by this way are a little lower as shown in Table II (The symmetrical disulfide R^1-S-S-R^1 is a by-product).

Table II - Preparation of unsymmetrical disulfides from symmetrical disulfides

Substrate	R^1S^+	Product^7		Isolated yield (%)
$PhCH_2$-S-S-CH_2Ph	PhS^+	Ph-CH_2-S-S-Ph	**3**	47
CH_3-S-S-CH_3	PhS^+	Ph-S-S-CH_3	**6**	60
Ph-S-S-Ph	$PhCH_2S^+$	Ph-S-S-CH_2-Ph	**3**	47
$PhCH_2$-S-S-CH_2Ph	CH_3S^+	Ph-CH_2-S-S-CH_3	**5**	55
CH_3-S-S-CH_3	$PhCH_2S^+$	CH_3-S-S-CH_2Ph	**5**	54

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References and notes

1. Boustanay K.S. and Sullivan A.B., *Tetrahedron Lett.*, **1970**, 3547-3549.
2. Armitage D.A., Clark M.J. and Tso C.C., *J. Chem. Soc., Perkin Trans.* 1, **1972**, 860-863.
3. Brois S.J., Pilot F.J. and Barnum H.W., *J. Am. Chem. Soc.*, **1970**, *92*, 7629-7631.
4. Douglass I.B., Martin F.T. and Addor R., *J. Org. Chem.*, **1951**, *16*, 1297-1302.
5. Leriverend C. and Metzner P., *Synthesis*, **1994**, 761-762.
6. a) Le Guillanton G., Boryczka S., Elothmani D., Do Q.T. and Simonet J., *Denki Kagaku, Oyobi Kogyo Butsuri Kagaku*, **1994**, *62*, 1283-1286. b) Boryczka S., Elothmani D., Do Q.T., Simonet J. and Le Guillanton G., *J. Electrochem. Soc.*, **1996**, *143* (12), 4027-4032.
7. All unsymmetrical disulfides are liquid. Mass and ^1H NMR ($CDCl_3$, δ) spectra: **1**, $C_9H_{12}S_2$, m/z 184; δ = 7.13-7.66 (m, 5H), 2.71 (J = 7 Hz, t, 2H), 1.73 (J = 7 Hz, m, 2H), 0.96 (J = 7 Hz, t, 3H). **2**, $C_{10}H_{14}S_2$, m/z 198; δ = 7.13-7.63 (m, 5H), 1.3 (s, 9H). **3** $C_{13}H_{12}S_2$, m/z 232; δ = 7.13-7.63 (m, 5H), 7.33 (s, 5H), 3.93 (s, 2H). **4** $C_{11}H_{16}S_2$, m/z 212; δ = 7.30 (s, 5H), 3.90 (s, 2H), 1.3 (s, 9H). **5** $C_8H_{10}S_2$, m/z 170; δ = 7.33 (s, 5H), 3.93 (s, 2H), 2.13 (s, 3H). **6** $C_7H_8S_2$, m/z 156; δ = 7.16-7.61 (m, 5H), 2.36 (s, 3H).

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