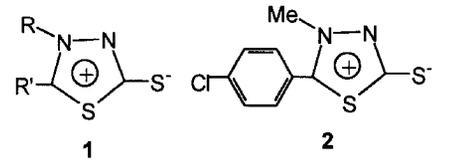
An Interesting Isomerization: Synthesis of Mesoionic 5-Arylamino-1,3,4-Thiadiazolium-2-Thiolates by Using ω-Bromo-ω-(1*H*-1,2,4-Triazol-1-yl)acetophenone as Catalyst

Chang-Hu Chu[a] (• • • •), Xin-Ping Hui[a] (• • • •), Peng-Fei Xu[a] (• • • •),
Zi-Yi Zhang*[a] (• • • •), Zhi-Chun Li[b] (• • • •) and Ren-An Liao[b] (• • • •)
[a]*Department of Chemistry, National Laboratory of Applied Organic Chemistry, Lanzhou University, Lanzhou 730000, P. R. China*
[b]*State Key Laboratory of Elemento-Organic Chemistry, Nankai University, Tianjin 300071, P. R. China*

Mesoionic 5-arylamino-1,3,4-thiadiazolium-2-thiolates **7a-f** were prepared by the isomerization of 5-arylamino-1,3,4-thiadiazol-2-thiones **5a-f** by using ω-bromo-ω-(1*H*-1,2,4-triazol-1-yl)acetophenone **6** as catalyst. All the structures of mesoionic synthesized were confirmed by elemental analyses, ^{1}H NMR, IR and MS spectral data. We have also determined the x-ray photoelectron spectroscopy (XPS) of the mesoionic and their precursors. A comparison of XPS spectra between the mesoionic and their precursors showed that the charge separation in mesoionic is distinctly larger than in their precursors.

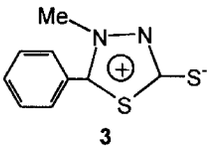
INTRODUCTION

Mesoionic compounds have received much attention and have been extensively studied for their unique structures, reaction behavior and pharmaceutical activities.[1] The chemistry of mesoionic was comprehensively reviewed.[2] 1,3,4-Thiadiazolium-2-thiolates are a well known type of mesoionic. Grashey[3] reported different routes to synthesize mesoionic compounds **1** *via* the condensation of 3-aryldithiocarbazate with aldehyde, followed by oxidation and disproportion or by condensation of 3-aryldithiocarbazate with acyl chloride. Schonberg[4] recognized that the derivatives **1** were resonance hybrids of several dipolar canonical forms. Patsch[5] discussed the x-ray photoelectron spectroscopy (XPS) of 4-methyl-5-aryl-1,3,4-thiadiazolium-2-thiolates **2**, **3** and 3-methyl-5-phenyl-1,3,4-thiadiazol-5-thione **4**. The results showed that the charge separation in **4** is distinctly smaller than in **3**. In all these 1,3,4-thiadiazolium-2-thiolate mesoionc compounds, 4-nitrogen was substituted by alkyl or other groups. The mesoionic compounds without substituted group in 4-nitrogen have not been reported. So, we wish to report herein the synthesis of mesoionic 5-arylamino-1,3,4-thiadiazolium-2-thiolates by using ω-bromo-ω-(1*H*-1,2,4-triazol-1-yl)acetophenone as catalyst.

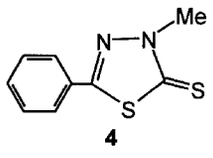


1

2



3



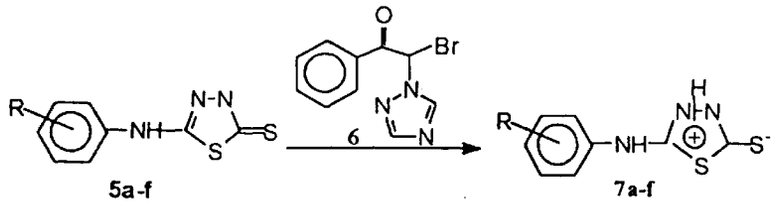
4

RESULTS AND DISCUSSION

A solution of ω-bromo-ω-(1*H*-1,2,4-triazol-1-yl)acetophenone[6] **6** in absolute ethanol was added dropwise to a solution of 5-arylamino-1,3,4-thiadiazol-2-thiones **5a-f** in absolute ethanol at room temperature; much of a deep colored solid substance was produced in high yield (Scheme I). They were proved to be a new type of mesoionic **7a-f**, which were isomeric with 5-arylamino-1,3,4-thiadiazol-2-thiones **5a-f**. At the same time, traces of ω-(5-arylamino-1,3,4-thiadiazol-2-thio)-ω-(1*H*-1,2,4-triazol-1-yl)acetophenones **9a-f** were isolated. ω-Bromo-ω-(1*H*-1,2,4-triazol-1-yl)acetophenone **6** was proved to play an important role of catalysis in this isomeric reaction. Mesoionic 1,3,4-thidiazolium-2-thiolates **7a-f** were prepared for the first time by an isomeric procedure. Their isolation and purification are facile.

We also smoothly afforded ω-(5-aryl-1,3,4-oxadiazol-2-thio)-[6] and ω-(5-aryl-1,2,4-triazol-3-thio)-ω-(1*H*-1,2,4-triazol-1-yl)acetophenones[7] by the condensation of ω-bromo-ω-(1*H*-1,2,4-triazol-1-yl)acetophenone with 5-aryl-1,3,4-oxidiazol-2-thiones and 5-aryl-1,2,4-triazol-3-thiones, but we did not get any such compounds whose properties were similar to mesoionic **7** in the two condensation reactions. Later, we prepared ω-(5-arylamino-1,3,4-thiadiazol-2-thio)-ω-(1*H*-1,2,4-triazol-1-yl)acetophenones in the presence of concen-

Scheme I



R=H(**7a**), 4-Cl(**7b**), 4-MeO(**7c**), 4-EtO(**7d**), 4-Me(**7e**), 3-Me(**7f**)

trated hydrochloric acid at lower temperature in moderate yields.[8]

The formation of mesoionic **7** may be explained that both phenylcarbonyl and 1*H*-1,2,4-triazol groups contacting α carbon of ω-bromo-ω-(1*H*-1,2,4-triazol-1-yl)acetophenone **6** are electron withdrawing groups, so the ion pair (Br^--C^+) formed easily. When **6** was added into 5-arylamino-1,3,4-thiadiazol-2-thiones **5**, the intermediates **8** were formed firstly, and then mesoionic **7** were obtained as main products by migrating hydrogen cation to *N*-4 position and losing **6** from **8**. At the same time, traces of ω-(5-arylamino-1,3,4-thiadiazol-2-thio)-ω-(1*H*-1,2,4-triazol-1-yl)acetophenones **9a-f** were produced as byproducts by dehydrogenbromide from **8**. The mesoionic **7a-f** are more stable than **9a-f** because the arylamino group can donate electrons to the 1,3,4-thiadiazole ring by *p*-π conjugation (Scheme II).

A comparison of melting points, solvability, ^{1}H NMR, IR, MS and XPS spectra showed that **5** and **7** were significantly different. Melting points of **7** were higher than their isomers **5.** [**5a**, 202-204 (204-206 °C, lit.[8]); **5b**, 133-134 (132 °C, lit. [8]); **5c**, 184-186 (186-188 °C, lit. [8]); **5d**, 205 (206-207 °C, lit.[8]); **5e**, 208-210 (216-218 °C, lit.[8]); **5f**, 180-182 (177-178 °C, lit.[8])]. Mesoionic **7** can only dissolve in a power solvent such as DMF and DMSO, but their isomers **5** can dissolve in ethanol, trichloromethane, methanol, acetone and other mild power solvent. The ^{1}H NMR spectra of mesoionic **7** and their isomers **5** indicated that the NH proton of **7** shifted to downfield more than **5** about 0.39-0.49 ppm [**5a,** 10.10 ppm (NH); **5b**, 10.26 ppm (NH); **5e**, 9.91 ppm (NH)]. Furthermore, IR and MS spectra of **5** and **7** were also different. [**5a,** 3075 (m), 2995 (m), 2940 (m), 1600 (s), 1570 (s), 1500 (s), 1475 (s), 1300 (s), 1060 (s) cm^{-1}; **5b**, 3220 (m), 3100 (s), 2960 (m), 2900 (m), 1600 (s), 1560 (s), 1485 (s), 1400 (s), 1318 (s), 1050 (s) cm^{-1}. MS data of **5d** and **7d**: **5d**, 253 (M^+, 100), 252 (10), 227 (2), 226 (5), 225 (15), 224 (36), 221 (2), 180 (5), 166 (8), 165 (12), 162 (6), 152 (11), 151 (19), 149 (3), 134 (25), 133 (20), 126 (3), 123 (6), 121 (6), 120 (7), 119 (4), 117 (4), 108 (21), 107 (6), 96 (2), 95 (2), 94 (5). **7d**, 253 (M^+, 100), 225 (14), 224 (47), 165 (8), 162 (30), 152 (8), 151 (21), 147 (28), 134 (71), 133 (22), 119 (52), 108 (17), 91 (11), 77 (8), 76 (23)]. The difference of XPS spectra was obvious (Table 1 and Table 2). In mesoionic **7,** N_{1s} has three types of binding energy, which is attributed to three different chemical circumstances of nitrogen atoms. While in **5**, two types of binding energy are due to two different chemical circumstances of nitrogen atoms. The reason may be the chemical circumstances of

Scheme II

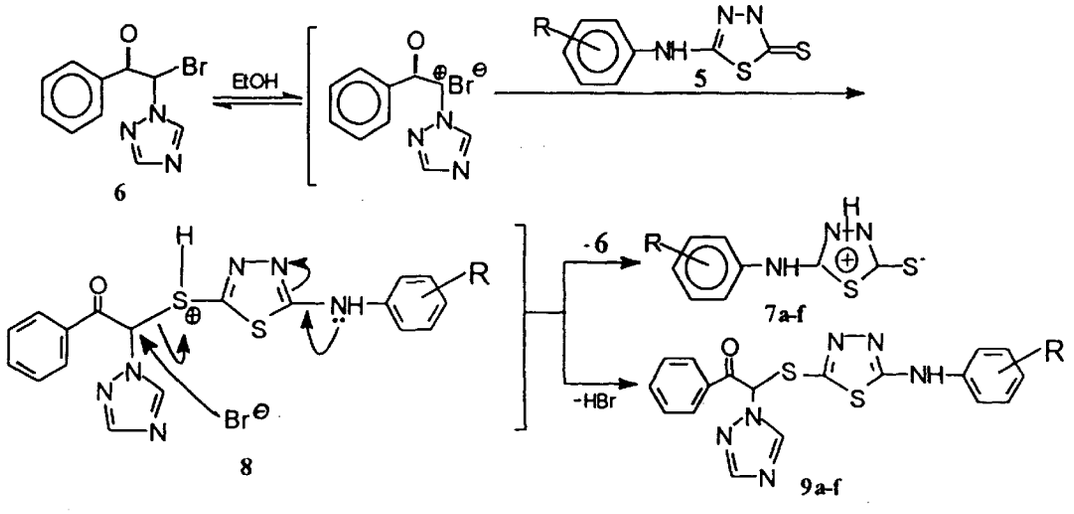


Table 1. N_{1s} Binding Energy of Compounds **5a-f** and **7a-f**

Compd.	N_{1s} Binding energy (eV)			
5a	399.92		399.26	
7a	402.40	400.28		399.45
5b	400.97		399.80	
7b	400.81	400.13		399.26
5c	400.79		397.13	
7c	402.11	401.13		398.80
5d	400.03		397.13	
7d	400.12	399.66		397.37
5e	400.82		399.69	
7e	400.77	400.31		397.75
5f	400.86		399.69	
7f	400.21	399.40		398.46

annular nitrogen in **7** were different but almost the same in **5**. These facts were similar to those reported in the literature.[5] Similarly, the binding energy of sulfur $S_{2p}^{1/2}$ and $S_{2p}^{3/2}$ in mesoionic **7** is higher than that of their isomers **5**. Based on the facts mentioned above, the structures of mesoionic **7** can be confirmed.

Table 2. $S_{2p}^{1/2}$ and $S_{2p}^{3/2}$ Binding Energy of Compounds **5a-f** and **7a-f**

Compd.	S_{2p} Binding energy (eV)	
	7	**5**
a	$S_{2p}^{1/2}$, 166.23 $S_{2p}^{3/2}$, 165.84	$S_{2p}^{1/2}$, 165.55 $S_{2p}^{3/2}$, 164.55
	$S_{2p}^{1/2}$, 164.79 $S_{2p}^{3/2}$, 164.60	$S_{2p}^{1/2}$, 164.22 $S_{2p}^{3/2}$, 163.54
b	$S_{2p}^{1/2}$, 166.23 $S_{2p}^{3/2}$, 165.10	$S_{2p}^{1/2}$, 165.57 $S_{2p}^{3/2}$, 164.32
	$S_{2p}^{1/2}$, 164.91 $S_{2p}^{3/2}$, 164.08	$S_{2p}^{1/2}$, 163.11 $S_{2p}^{3/2}$, 162.07
c	$S_{2p}^{1/2}$, 166.85 $S_{2p}^{3/2}$, 165.52	$S_{2p}^{1/2}$, 165.45 $S_{2p}^{3/2}$, 164.17
	$S_{2p}^{1/2}$, 164.25 $S_{2p}^{3/2}$, 163.20	$S_{2p}^{1/2}$, 162.92 $S_{2p}^{3/2}$, 161.76
d	$S_{2p}^{1/2}$, 166.33 $S_{2p}^{3/2}$, 165.66	$S_{2p}^{1/2}$, 164.81 $S_{2p}^{3/2}$, 163.74
	$S_{2p}^{1/2}$, 164.95 $S_{2p}^{3/2}$, 164.30	$S_{2p}^{1/2}$, 162.67 $S_{2p}^{3/2}$, 161.63
e	$S_{2p}^{1/2}$, 166.71 $S_{2p}^{3/2}$, 165.82	$S_{2p}^{1/2}$, 165.83 $S_{2p}^{3/2}$, 164.70
	$S_{2p}^{1/2}$, 165.37 $S_{2p}^{3/2}$, 164.71	$S_{2p}^{1/2}$, 163.72 $S_{2p}^{3/2}$, 162.38
f	$S_{2p}^{1/2}$, 165.58 $S_{2p}^{3/2}$, 164.46	$S_{2p}^{1/2}$, 165.62 $S_{2p}^{3/2}$, 164.39
	$S_{2p}^{1/2}$, 164.34 $S_{2p}^{3/2}$, 163.42	$S_{2p}^{1/2}$, 163.21 $S_{2p}^{3/2}$, 162.07

EXPERIMENTAL SECTION

The melting points were determined on a Kolfler melting point apparatus and were uncorrected. Elemental analyses were carried out on a Yanaco CHN Corder MT-3 analyzer. IR spectra were obtained in KBr discs on a Nicolet FT-IR 170SX spectrometer. MS were performed on a HP-5988A spectrometer (EI at 70 eV). ^{1}H NMR spectra (DMSO-d_6) were recorded on a JEOL FX-90X instrument with TMS as an internal standard. XPS spectra were performed on PHI-5702 XPS/AES system X-ray photoelectronic spectrometer.

General procedure for the preparation of mesoionic 5-arylamino-1,3,4-thiadiazolium-2-thiolates 7a-f

To a solution of 5-arylamino-1,3,4-thiadiazol-2-thiones **5** (2 mmol) in absolute ethanol (25 mL), ω-bromo-ω-(1*H*-1,2,4-triazol-1-yl)acetophenone **6** (2 mmol) in absolute ethanol (25 mL) were added dropwise. After a few minutes, a colored solid was produced, collected by filtration and recrystallized from DMF-EtOH to afford **7a-f**.

5-Phenylamino-1,3,4-thiadiazolium-2-thiolate 7a

Yield, 85%; mp 223-224°C. IR ν_{max} (KBr) 3246 (m), 3016 (m), 1603 (s), 1552 (s), 1480 (s), 1443 (s), 1372 (s), 1168 (m), 1115 (s), 1035 (m) cm^{-1}; ^{1}H NMR (DMSO-d_6) δ 10.52 (s, 1H, NH), 7.68-6.96 (m, 5H, ArH); Anal. Calcd. for $C_8H_7N_3S_2$: C, 45.91; H, 3.37; N, 20.08; Found: C, 46.27; H, 3.19; N, 19.58.

5-(*p*-Chlorophenylamino-1,3,4-thiadiazolium-2-thiolate 7b

Yield, 90%; mp 244-245 °C. IR ν_{max} (KBr) 3252 (m), 3059 (m), 1659 (m), 1605 (s), 1549 (s), 1481 (s), 1234 (s), 1179 (s), 1087 (s), 1037 (s) cm^{-1}; ^{1}H NMR (DMSO-d_6) δ 10.65 (s, 1H, NH), 7.60 (d, 2H, J = 7.2 Hz, ArH), 7.36 (d, 2H, J = 7.2 Hz, ArH); Anal. Calcd. for $C_8H_6ClN_3S_2$: C, 39.42; H, 2.48; N, 17.24; Found: C, 39.77; H, 2.64; N, 16.97.

5-(*p*-Methoxyphenylamino-1,3,4-thiadiazolium-2-thiolate 7c

Yield, 94%; mp 253-254 °C. IR ν_{max} (KBr) 3240 (m), 3061 (m), 1603 (s), 1556 (s), 1515 (s), 1488 (s), 1373 (m), 1172 (m), 1112 (m), 1032 (s) cm^{-1}; ^{1}H NMR (DMSO-d_6) δ 10.39 (s, 1H, NH), 7.84 (d, 2H, J = 7.2 Hz, ArH), 6.90 (d, 2H, J = 7.2 Hz, ArH), 3.76 (s, 3H, CH_3O); Anal. Calcd. for $C_9H_9N_3OS_2$: C, 45.17; H, 3.79; N, 17.56; Found: C, 45.38, H,

3.37; N, 17.08.

5-(*p*-Ethoxyphenylamino-1,3,4-thiadiazolium-2-thiolate 7d

Yield 87%; mp 240-241 °C. IR ν_{max} (KBr) 3245 (m), 3062 (m), 2975 (m), 1603 (s), 1553 (s), 1485 (s), 1254 (s), 1172 (m), 1114 (m), 1049 (m) cm^{-1}; ^1H NMR (DMSO-d_6) δ 10.52 (s, 1H, NH), 7.49 (d, 2H, J = 8.8 Hz, ArH), 6.83 (d, 2H, J = 8.8 Hz, ArH), 3.95 (q, 2H, CH_2), 1.31 (t, 3H, CH_3); Anal. Calcd. for $C_{10}H_{11}N_3OS_2$: C, 47.41; H, 4.38; N, 16.59; Found: C, 47.87; H, 4.18; N, 16.60.

5-(*p*-Methylphenylamino-1,3,4-thiadiazolium-2-thiolate 7e

Yield 89%; mp 225-226 °C. IR ν_{max} (KBr) 3248 (m), 3057 (m), 1606 (s), 1550 (s), 1484 (s), 1372 (s), 1166 (m), 1107 (m), 1037 (m), 806 (s) cm^{-1}; ^1H NMR (DMSO-d_6) δ 10.40 (s, 1H, NH), 7.44 (d, 2H, J = 8.8 Hz, ArH), 6.98 (d, 2H, J = 8.8 Hz, ArH), 2.32 (s, 3H, CH_3); Anal. Calcd. for $C_9H_9N_3S_2$: C, 48.41; H, 4.06; N, 18.82; Found: C, 48.50; H, 4.11; N, 19.08.

5-(*m*-Methylphenylamino-1,3,4-thiadiazolium-2-thiolate 7f

Yield 92%; mp 218-219 °C. IR ν_{max} (KBr): 2925 (m), 1593 (s), 1571 (s), 1490 (m), 1449 (s), 1419 (s), 1109 (s) cm^{-1}; ^1H NMR (DMSO-d_6) δ 10.54 (s, 1H, NH), 7.44-6.84 (m, 4H, ArH), 2.32 (s, 3H, CH_3); Anal. Calcd. for $C_9H_9N_3S_2$: C, 48.41; H, 4.06; N, 18.82; Found: C, 48.51; H, 4.28; N, 17.78.

ACKNOWLEDGEMENT

We are grateful for the financial support from the State Key Laboratory of Elemento-Organic Chemistry of Nankai University.

Received September 28, 1999.

Key Words

Isomerization; 1*H*-1,2,4-Triazole; 1,3,4-Thiadiazolium-2-thiolate; X-Ray photoelectron spectroscopy.

REFERENCES

1. Shuki, A.; Jiro, M.; Naomitsu, A.; Yasuo, B. *J. Chem. Soc. Perkin Trans I* **1995**, 1989.
2. Newton, C. G.; Ramsden, C. A. *Tetrahedron* **1982**, *38*, 2965.
3. Grashey, R.; Baumann, M.; Lubos, W. D. *Tetrahedron Lett.* **1968**, *56*, 5881.
4. Schonberg, A. *J. Chem. Soc.* **1938**, 824.
5. Patsch, M.; Thieme, P. *Angew. Chem. Inter. Edit.* **1971**, *10 (8)*, 569.
6. Chu, C. H.; Sun, X. W.; Sun, L.; Zhang, Z. Y.; Li, Z. C.; Liao, R. A. *J. Chin. Chem. Soc.* **1999**, *46*, 229.
7. Chu, C. H.; Zhang, Y.; Sun, X. W.; Zhang, Z. Y.; Li, Z. C.; Liao, R. A. *Indian J. Chem.* **2000**, *39B* (*9*).
8. Chu, C. H.; Hui, X. P.; Sun, X. W.; Zhang, Z. Y.; Li, Z. C.; Liao, R. A. *Indian J. Chem.* (accepted).