Role of 1,4-dimethylpiperazine in radical cyclizations

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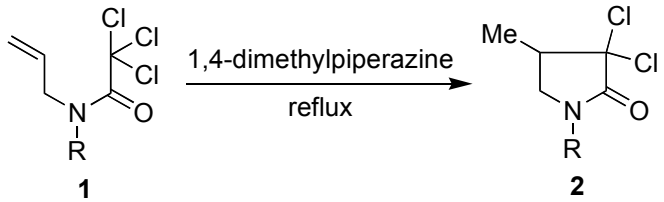
Abstract
Radical cyclization of *o*-ethenyltrichloroacetanilides in boiling 1,4-dimethylpiperazine was examined with a comparison of the mode of radical cyclizations under a Bu_3SnH-mediated condition. It was found that an attack of a hydrogen atom on the cyclized radical intermediates occurred more rapidly in 1,4-dimethylpiperazine than under the Bu_3SnH-mediated condition. This phenomenon was also observed in similar reactions of *N*-ethenyltrichloroacetamide.

Keywords: Neophyl rearrangement, radical cyclization, single electron transfer, trichloroacetamide

Introduction

A previous study in our laboratory revealed that treatment of *N*-allylic trichloroacetamides **1** in boiling 1,4-dimethylpiperazine gave the corresponding 5-membered lactams **2** in good yields (Scheme 1).[1] Formation of **2** might be a result of radical cyclization that proceeded *via* a single electron transfer reaction from the nitrogen atom of 1,4-dimethylpiperazine to the precursor **1**. This reaction will provide an unprecedented method for radical cyclization without using a combination of a radical initiator such as azobis(isobutyronitrile) (AIBN) and a hydrogen atom donor such as tributyltin hydride (Bu_3SnH).[2-8]



1 **2**

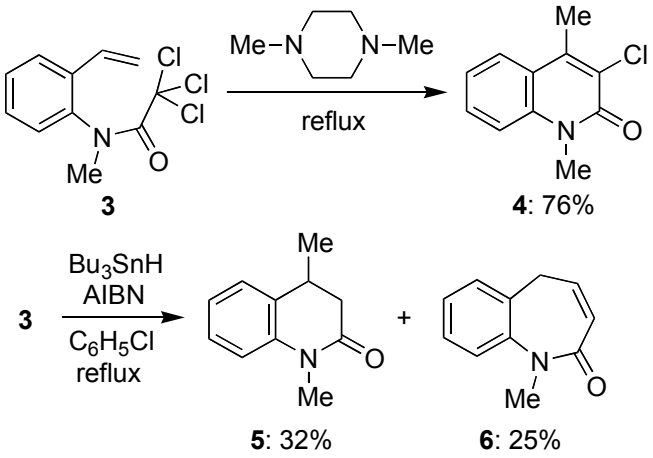
Scheme 1

We have now examined the reaction of *o*-ethenyltrichloroacetanilides in boiling

1,4-dimethylpiperazine with a comparison of the mode of radical cyclizations under a Bu_3SnH-mediated condition, and found that an attack of a hydrogen atom on the cyclized radical intermediates occurred more rapidly in 1,4-dimethylpiperazine than under the Bu_3SnH-mediated condition. This phenomenon was also observed in similar reactions of *N*-ethenyltrichloroacetamide. The results of our works in this area are presented in this paper.

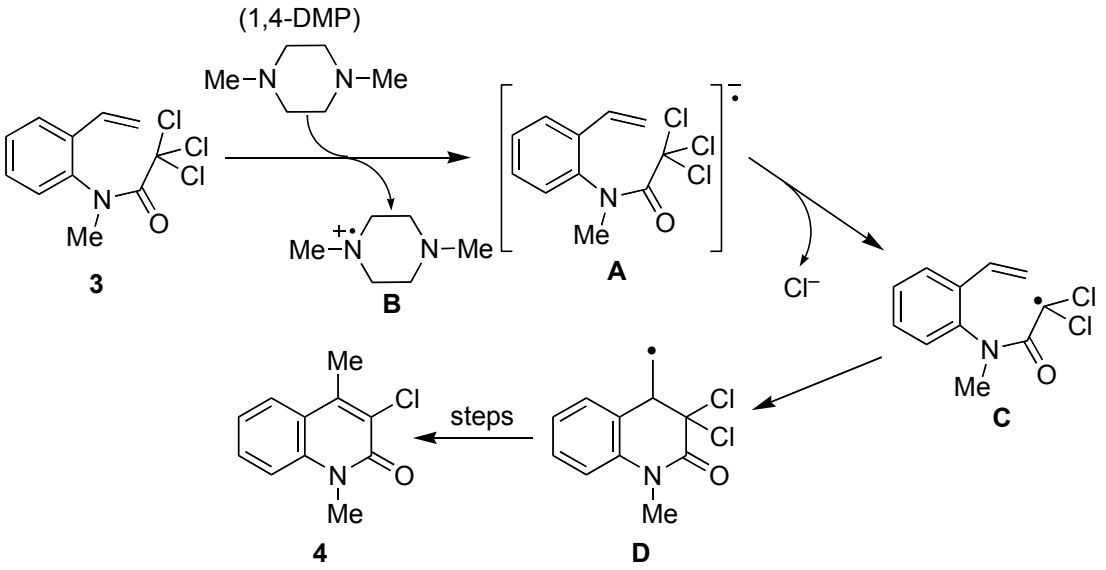
Results and Discussion

o-Ethenyltrichloroacetanilide **3** was prepared by acylation of *o*-ethenyl-*N*-methylaniline with trichloroacetyl chloride. When compound **3** was heated in boiling 1,4-dimethylpiperazine for 20 min, cyclized product **4** was obtained in 76% yield (Scheme 2). On the other hand, treatment of **3** with Bu_3SnH in the presence of AIBN (using the slow addition technique) in boiling chlorobenzene gave two compounds **5** and **6** in 32% and 25% yields, respectively.



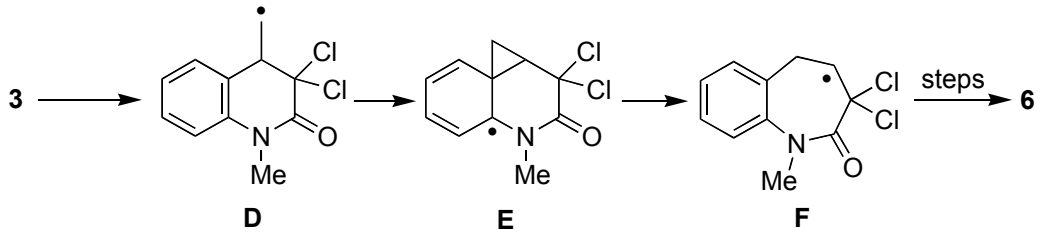
Scheme 2

Formation of **4** from **3** can be explained as follows (Scheme 3). A single electron transfer reaction from a nitrogen atom of 1,4-dimethylpiperazine (1,4-DMP) to the starting compound **3** gives radical anion **A** together with radical cation **B**. Removal of the chloride anion of **A** affords radical **C**, which then undergoes cyclization in a 6-*exo*-*trig* manner to give cyclized radical **D**. An attack of radical **D** on the hydrogen atom of radical cation **B** or 1,4-dimethylpiperazine (1,4-DMP) itself followed by elimination of hydrogen chloride gives the observed product **4**.



Scheme 3

Formation of **5** from **3** may proceed *via* an attack of Bu_3SnH on the radical center of **D** and successive reduction of the two chlorine atoms by Bu_3SnH. Formation of 7-membered unsaturated lactam **6** was presumed to be not a result of a direct 7-*endo* cyclization of the radical formed from **3** but a result of a neophyl rearrangement of intermediate **D** to give **F** through the intermediacy of radical **E** (Scheme 4).

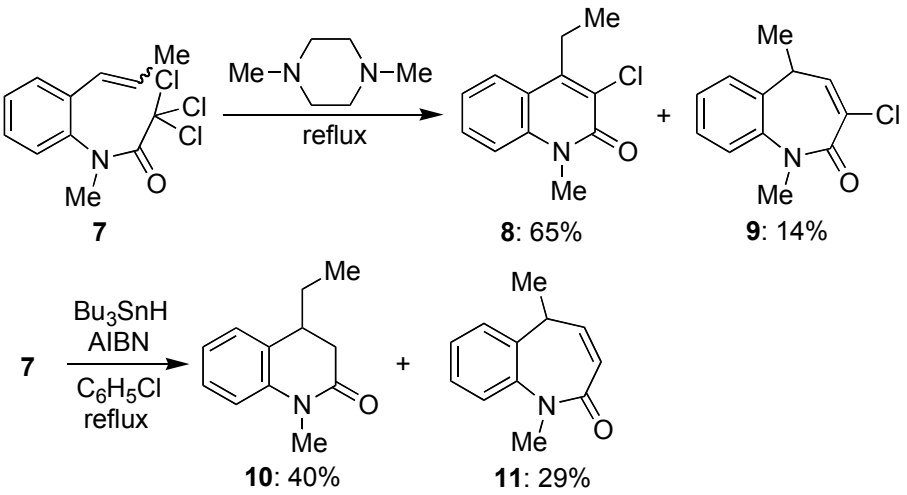


Scheme 4

When the concentration of the hydrogen atom source is high in the radical reaction media, an initially cyclized radical intermediate (such as **D**) is rapidly reduced by an attack of a hydrogen atom, whereas when the concentration of the hydrogen atom source is low, the cyclized radical can undergo another reaction such as neophyl rearrangement before attack by a hydrogen atom. Therefore, no formation of the neophyl rearrangement product in boiling 1,4-dimethylpiperazine might indicate that the concentration of the hydrogen atom source was high, and formation of neophyl rearrangement product **6** from **3** showed that the concentration of the hydrogen atom source under the Bu_3SnH-mediated condition was low.

Treatment of compound **7** in boiling 1,4-dimethylpiperazine afforded **8** and **9** in 65% and 14%

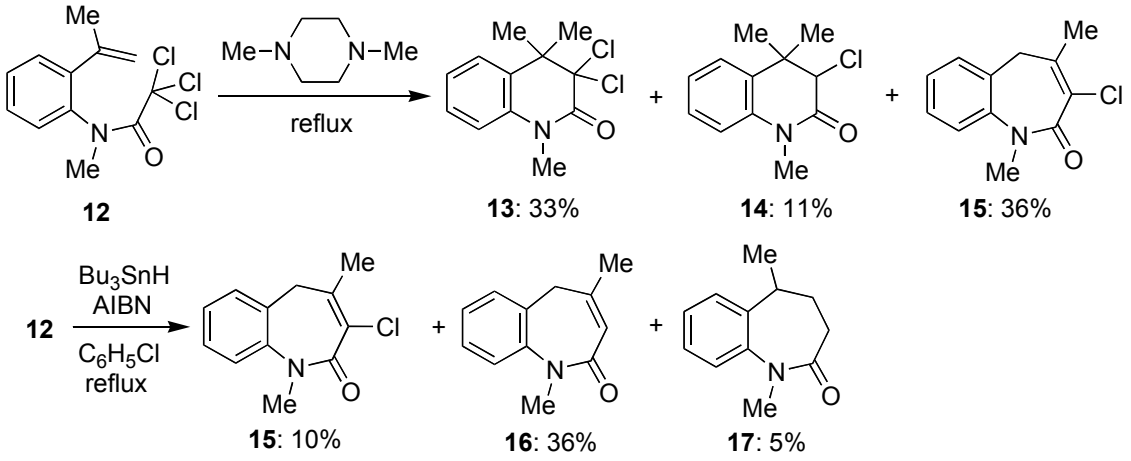
yields, respectively, whereas reaction of **7** under the AIBN-Bu_3SnH condition gave the products **10** and **11** in 40% and 29% yields, respectively (Scheme 5).



Scheme 5

It is assumed that compounds **8** and **10** are 6-*exo* cyclization products and that compounds **9** and **11** are neophyl rearrangement products. The product ratio of 6-*exo* cyclization product **8** and a neophyl rearrangement product **9** in boiling 1,4-dimethylpiperazine was 4.6:1 and that of **10**:**11** under the Bu_3SnH-mediated condition was 1.4:1. These results also indicated that the concentration of the hydrogen atom source was higher in boiling 1,4-dimethylpiperpazine than under the Bu_3SnH-mediated condition.

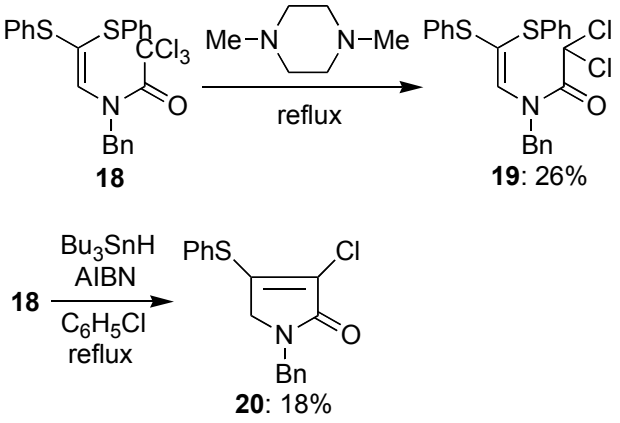
The cyclization of **12**, which was prepared by *N*-methylation of *o*-(1-methylethenyl)trichloroacetanilide, in boiling 1,4-dimethylpiperazine gave 6-*exo* cyclization products **13** and **14** and the neophyl rearrangement product **15** in 33%, 11% and 36% yields, respectively, and the reaction of **12** with AIBN-Bu_3SnH gave the neophyl rearrangement product **15** and **16** and 7-*endo* cyclization product **17** in 10%, 36% and 5% yields, respectively (Scheme 6). No formation of a 6-*exo* cyclization product under the Bu_3SnH-mediated conditions also strongly indicated that the concentration of the hydrogen atom source under the Bu_3SnH-mediated condition was low.



Scheme 6

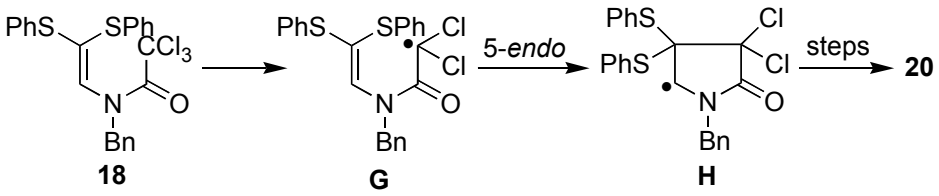
It is recognized that 5-*endo-trig* cyclization of 4-pentenyl radicals is a disfavored process due to the stereoelectronic disadvantage in the attack of the radical center on the alkenic bond.[9] We have found, however, that 5-*endo-trig* radical cyclizations occurred smoothly in some *N*-vinylic α-haloacetamides.[10] We turned our attention to enamide **18**, which was prepared by trichloroacetylation of imine from 2,2-bis(phenylthio)acetaldehyde and benzylamine.

We could not isolate any cyclized product by heating **18** in boiling 1,4-dimethylpiperazine but obtained mono-dechlorinated compound **19** in 26% yield (Scheme 7). On the other hand, compound **20** was isolated in 18% yield together with several unidentified products by treatment of **18** with AIBN and Bu_3SnH in boiling chlorobenzene.



Scheme 7

Formation of **20** could be explained by 5-*endo-trig* cyclization of radical **G** followed by chemical transformations of the resultant radical intermediate **H** (Scheme 8).



Scheme 8

When the concentration of the hydrogen atom source is high, a 4-pentenyl radical intermediate such as **G** may be reduced immediately by a hydrogen atom. Therefore, it is assumed that heating **18** in boiling 1,4-dimethylpiparazine, in which the concentration of the hydrogen atom source is high, gives the reduction product, and cyclized products are obtained under the Bu_3SnH-mediated condition, in which the concentration of the hydrogen atom source is low.

In conclusion, radical cyclizations of a range of 2-ethenyltrichloroacetanilides in boiling 1,4-dimethylpiperazine and under Bu_3SnH-mediated conditions have revealed that the condition using 1,4-dimethylpiperazine works more effectively as a hydrogen atom donor than does the condition using Bu_3SnH.

Experimental Section

2'-Ethenyl-*N*-methyltrichloroacetanilide (3). To a solution of 2-ethenyl-*N*-methylaniline[11] (344 mg, 2.58 mmol) in CH_2Cl_2 (10 mL) were added trichloroacetyl chloride (0.35 mL. 3.10 mmol) and triethylamine (0.54 mL, 3.87 mmol) at 0 °C and the mixture was stirred at room temperature for 10 min. The reaction mixture was diluted with water and extracted CH_2Cl_2, and the extract was dried ($MgSO_4$) and concentrated. The residue was chromatographed on silica gel (hexane/AcOEt, 20:1) to give **3** (691 mg, 96%) as an oil, whose ^1H and ^{13}C NMR spectra showed it to be a mixture of rotamers; IR ($CHCl_3$) cm^{-1}: 1680; ^1H NMR (270 MHz, $CDCl_3$) δ: 3.32 (3H x 3/5, br s), 3.62 (3H x 2/5, br s), 5.41 (1H, d, J=11.0 Hz), 5.80 (1H, dd, J=17.5, 1.0 Hz), 6.77 (1H, m), 7.26-7.40 (3H, m), 7.63 (1H, d, J=7.6 Hz); ^{13}C NMR (125 MHz, $CDCl_3$) δ: 42.2, 80.4, 117.3, 126.2, 128.3, 129.1, 129.4, 131.0, 131.9, 135.4, 140.1; HRMS Calcd for $C_{11}H_{10}Cl_3NO$: 276.9828, found: 276.9826.

3-Chloro-1,4-dimethylquinolin-2(1*H*)-one (4). A solution of compound **3** (163 mg, 0.59 mmol) in 1,4-dimethylpiperazine (60 mL) was heated at reflux for 20 min. The reaction mixture was diluted with water and extracted with CH_2Cl_2. The organic layer was dried ($MgSO_4$) and concentrated, and the residue was chromatographed on silica gel (hexane/AcOEt, 10:1) to give **4** (94 mg, 76%) as colorless crystals; mp 186-186.5 °C (from hexane). IR ($CHCl_3$) cm^{-1}: 1640. ^1H NMR (270 MHz, $CDCl_3$) δ: 2.65 (3H, s), 3.80 (3H, s), 7.30 (2H, ddd, J=8.1, 7.1, 1.2 Hz), 7.39 (1H, dd, J=8.4, 0.8 Hz), 7.59 (1H, ddd, J=8.7, 7.2, 1.5 Hz), 7.77 (1H, dd, J=8.1, 1.5 Hz); ^{13}C NMR (125 MHz, $CDCl_3$) δ: 16.4, 30.7, 114.5, 120.6, 122.6, 125.4, 126.3, 130.4, 137.9, 142.4, 158.0. Anal. Calcd for $C_{11}H_{10}ClNO$: C, 63.62; H, 4.85; N, 6.75. Found: C, 63.70; H, 4.84; N, 6.79.

3,4-Dihydro-1,4-dimethylquinolin-2(1*H*)-one (5) and 1,5-dihydro-1-methyl-2*H*-1-benzazepin-2-one (6). A solution of AIBN (16 mg, 0.1 mmol) and Bu_3SnH (218 mg, 0.75 mmol) in chlorobenzene (25 mL) was added dropwise using a syringe pump to a solution of **3** (139 mg, 0.5 mmol) in chlorobenzene (25 mL) at reflux during 1.5 h. After consumption of the starting material, to the reaction mixture was added a solution of AIBN (16 mg, 0.1 mmol) and Bu_3SnH (218 mg, 0.75 mmol) in chlorobenzene (2 mL) and the mixture was heated at reflux for 30 min. The solvent was removed and the residue was chromatographed on silica gel containing KF (10%) (hexane/AcOEt, 4:1). The first eluate gave **5**[12] (28 mg, 32%) as an oil; IR ($CHCl_3$) cm^{-1}: 1655; ^1H NMR (500 MHz, $CDCl_3$) δ: 1.28 (3H, d, *J*=7.1 Hz), 2.46 (1H, dd, *J*=15,9, 7.6 Hz), 2.73 (1H, dd, *J*=15.8, 5.5 Hz), 3.02-3.10 (1H, m), 3.37 (3H, s), 6.99-7.07 (2H, m), 7.19-7.30 (2H, m); ^{13}C NMR (125 MHz, $CDCl_3$) δ: 19.2, 29.4, 30.3, 39.1, 114.7, 123.0, 126.2, 127.4, 131.0, 139.8, 169.8; HRMS Calcd for $C_{11}H_{13}NO$: 175.0997, found: 175.0996. The second eluate gave **6** (22 mg, 25%) as an oil; IR ($CHCl_3$) cm^{-1}: 1665; ^1H-NMR (500 MHz, $CDCl_3$) δ: 3.29 (2H, br s), 3.51 (3H, s), 5.91 (1H, d, *J*=10.7 Hz), 6.60 (1H, dt, *J*=10.7, 2.9 Hz), 7.10-7.15 (2H, m), 7.22-7.29 (2H, m); ^{13}C NMR (125 MHz, $CDCl_3$) δ: 32,1, 37.0, 122.1. 125.3, 125.4, 127.2, 127.7, 136.6, 141.3, 141.8, 167.2; HRMS Calcd for $C_{11}H_{11}NO$: 173.0841, found: 173.0839.

***N*-Methyl-2'-(1-propenyl)trichloroacetanilide (7).** According to a procedure similar to that described above for **3**, *N*-methyl-2-(1-propenyl)aniline[13] (1.79 g, 12.09 mmol) was acetylated with trichloroacetyl chloride (1.6 mL. 14.51 mmol) to give **7** (1.78 g, 81%) as colorless crystals, whose ^1H and ^{13}C NMR spectra showed it to be a mixture of rotamers; mp 88-89 °C (from hexane); ^1H NMR (500 MHz, $CDCl_3$) δ: 1.91 (3H, d, *J*=5.6 Hz), 3.31 (3H x 9/14, br s), 3.59 (3H x 5/14, br s), 6.22-6.44 (2H, m), 7.24-7.36 (3H, m), 7.54 (1H, d, *J*=7.6 Hz); ^{13}C NMR (125 MHz, $CDCl_3$) δ: 18.9, 42.1, 126.0, 126.1, 126.7, 127.1, 128.4, 129.0, 129.5, 135.8, 139.4, 161.0. Anal. Calcd for $C_{12}H_{12}Cl_3NO$: C, 49.26; H, 4.13; N, 4.79. Found: C, 49.25; H, 4.13; N, 4.80.

3-Chloro-4-ethyl-1-methylquinolin-2(1*H*)-one (8) and 3-chloro-1,5-dihydro-1,5-dimethyl-2*H*-1-benzazepin-2-one (9). A solution of compound **7** (146 mg. 0.5 mmol) in 1,4-dimethylpiperazine (2 mL) was heated at reflux for 20 min. A work-up similar to that described above for **4** and the crude materials were purified by chromatography on silica gel (hexane/AcOEt, 10:1). The first eluate gave **9** (16 mg, 14%) as an oil; IR ($CHCl_3$) cm^{-1}: 1645; ^1H NMR (500 MHz, $CDCl_3$) δ: 1.53 (3H, d, *J*=7.1 Hz), 3.55 (3H, s), 3.57-3.58 (1H, m), 6.43 (1H, d, *J*=5.9 Hz), 7.23-7.50 (4H, m); ^{13}C NMR (125 MHz, $CDCl_3$) δ: 15.7, 33.2. 38.0, 122.6, 122.9, 125.9, 127.0, 128.8, 140.3, 141.2, 144.6, 163.4; HRMS Calcd for $C_{12}H_{12}ClNO$: 221.0607, found: 221.0610. The second eluate gave **8** (72 mg, 65%) as colorless crystals; mp 91.5-92 °C (from hexane); IR ($CHCl_3$) cm^{-1}: 1640. ^1H NMR (500 MHz, $CDCl_3$) δ: 1.28 (3H, t, *J*=7.6 Hz), 3.10 (2H, q, *J*=7.6 Hz), 3.79 (3H, s), 7.27-7.32 (1H, m), 7.39 (1H, d, *J*=8.5), 7.57-7.60 (1H, m), 7.77 (1H, d, *J*=8.3 Hz). ^{13}C NMR (125 MHz, $CDCl_3$) δ: 12.5, 23.3, 30.7, 114.7, 119.4, 122.6, 125.1, 125.4, 130.3, 138.3, 147.8, 158.1. Anal. Calcd for $C_{12}H_{12}ClNO$: C, 65.02; H, 5.46; N, 6.32. Found: C, 64.88; H, 5.46; N, 6.53.

4-Ethyl-3,4-dihydro-1-methylquinolin-2(1*H*)-one (10) and 1,5-dihydro-1,5-dimethyl-2*H*-1-benzazepin-2-one (11). Using a procedure similar to that described above for the

preparation of **5** and **6**, compound **7** (146 mg, 0.5 mmol) was treated twice with AIBN (16 mg, 0.1 mmol) and Bu_3SnH (218 mg, 0.75 mmol). After a usual work-up, the residue was chromatographed on silica gel (hexane/AcOEt, 5:1). The first eluate gave **10**[11] (38 mg. 40%) as an oil; IR ($CHCl_3$) cm^{-1}: 1660; ^1H NMR (500 MHz, $CDCl_3$) δ: 0.93 (3H, t, *J*=7.6 Hz), 1.52-1.64 (2H, m), 2.61 (1H, dd, *J*=11.6, 6.1 Hz), 2.73-2.77 (2H, m), 3.35 (3H, s), 6.99-7.04 (2H, m), 7.14-7.16 (1H, m), 7.24-7.29 (1H, m); ^{13}C NMR (125 MHz, $CDCl_3$) δ: 11.4, 26.4, 29.2, 36.6, 37.6, 114.8, 122.6, 127.3, 127.7, 129.7, 139.7, 169.7. The second eluate gave **11** (27 mg, 29%) as an oil; IR ($CHCl_3$) cm^{-1}: 1655; ^1H NMR (500 MHz, $CDCl_3$) δ: 1.53 (3H, d, *J*=6.8 Hz), 3.51 (3H, s), 3.62 (1H, br s), 5.82 (1H, d, *J*=10.5 Hz), 6.28 (1H, br), 7,17-7.28 (4H, m); ^{13}C NMR (125 MHz, $CDCl_3$) δ: 16.0, 29.7, 37.1, 122.3, 123.4, 125.4, 126.8, 127.1, 140.6, 141.7, 148.5, 167.3; HRMS Calcd for $C_{12}H_{13}NO$: 187.0997, found: 187.0997.

***N*-Methyl-2'-(1-methylethenyl)trichloroacetanilide (12).** According to a procedure similar to that described above for **3**, 2'-(1-methylethenyl)trichloroacetanilide (2.20 g, quant.) was prepared from 2-(1-methylethenyl)aniline (1.0 mL, 7.34 mmol) and trichloroacetyl chloride (1.0 mL, 8.81 mmol). To a suspension of sodium hydride (289 mg. 7.22 mmol) in a combined solvent of THF and DMF = 1:1 (2 mL) was added a solution of 2'-(1-methylethenyl)trichloroacetanilide (1.34 g, 4.81.mmol) in THF (4 mL) at 0 °C and the mixture was stirred at the same temperature for 10 min. Methyl iodide (0.45 mL, 7.22 mmol) was added to the mixture and the mixture was stirred at room temperature for 30 min. The reaction mixture was diluted with water and extracted with AcOEt. The organic layer was washed with brine, dried ($MgSO_4$), and concentrated. The residue was chromatographed on silica gel (hexane/AcOEt, 30:1) to give **12** (1.18 g, 84%) as colorless crystals, whose ^1H and ^{13}C NMR spectra showed it to be a mixture of rotamers; mp 35-35.5 °C (from hexane); IR ($CHCl_3$) cm^{-1}: 1685; ^1H NMR (270 MHz, $CDCl_3$) δ: 2.08 (3H, s), 3.31 (3H x 1/5, br s), 3.62 (3H x 4/5, s), 4.98 (1H, br s), 5.21 (1H, br s), 7.19-7.35 (4H, m); ^{13}C-NMR (125 MHz, $CDCl_3$) δ: 23.4, 41.7, 115.9, 127.3, 127.9, 128.2, 128.4, 129.7, 140.8, 141.3, 142.1, 160.0. Anal. Calcd for $C_{12}H_{12}Cl_3NO$: C, 49.26; H, 4.13; N, 4.79. Found: C, 49.15; H, 4.11; N, 4.72.

3,3-Dichloro-3,4-dihydro-1,4,4-trimethylquinolin-2(1*H*)-one (13), 3-chloro-3,4-dihydro-1,4,4-trimethylquinolin-2(1*H*)-one (14) and 3-chloro-1,5-dihydro-1,4-dimethyl-2*H*-1-benzazepin-2-one (15). A solution of compound **12** (146 mg. 0.5 mmol) in 1,4-dimethylpiperazine (2 mL) was heated at reflux for 20 min. After a work-up similar to that described above for **4**, the residue was chromatographed on silica gel (hexane/AcOEt, 10:1). The first eluate gave **13** (43 mg, 33%) as colorless crystals; mp 96-97 °C (from hexane); IR ($CHCl_3$) cm^{-1}: 1690; ^1H NMR (500 MHz, $CDCl_3$) δ: 1.30 (3H, s), 1.80 (3H, s), 3.52 (3H, s), 7.07 (1H, d, *J*=8.3 Hz), 7.14-7.17 (1H, m), 7.32-7.37 (2H, m); ^{13}C NMR (125 MHz, $CDCl_3$) δ: 20.8, 25.1, 31.5, 46.8, 92.6, 115.2, 124.3, 125.1, 128.2, 131.7, 137.3, 161.9. Anal. Calcd for $C_{12}H_{13}Cl_2NO$: C, 55.83; H, 5.08; N, 5.43. Found: C, 55.66; H, 5.07; N, 5.36. The second eluate gave **14** (12 mg, 11%) as colorless crystals; mp 91-92 °C (from hexane); IR ($CHCl_3$) cm^{-1}: 1680; ^1H NMR (500 MHz, $CDCl_3$) δ: 1.31 (3H, s), 1.48 (3H, s), 3.44 (3H, s), 4.25 (1H, s), 7.06-7.34 (4H, m); ^{13}C NMR (125 MHz, $CDCl_3$) δ: 23.1, 26.1, 30.0, 38.5, 64.7, 115.1, 123.9, 125.2, 127.9, 131.2, 138.0, 165.3. Anal. Calcd for $C_{12}H_{14}ClNO$: C, 64.43; H, 6.31; N, 6.26. Found: C, 64.08; H, 6.30; N, 6.30. The

third eluate gave **15** (40 mg, 36%) as an oil; IR ($CHCl_3$) cm^{-1}: 1645; ^1H NMR (500 MHz, $CDCl_3$) δ: 2.11 (3H, s), 2.99 (1H, d, J=13.4 Hz), 3.55 (3H, s), 3.64 (1H, d, J=13.4 Hz), 7.13-7.31 (4H, m); ^{13}C NMR (125 MHz, $CDCl_3$) δ: 21.8, 37.6, 37.9, 121.0, 122.2, 125.7, 127.0, 127.6, 135.6, 141.2, 146.5, 164.1; HRMS Calcd for $C_{12}H_{12}ClNO$: 221.0607, found: 221.0606.

1,5-Dihydro-1,4-dimethyl-2*H*-1-benzazepin-2-one (16) and 1,3,4,5-tetrahydro-1,5-dimethyl-2*H*-1-benzazepin-2-one (17). Using a procedure similar to that described above for the preparation of **5** and **6**, compound **12** (146 mg, 0.5 mmol) was treated twice with AIBN (16 mg, 0.1 mmol) and Bu_3SnH (218 mg, 0.75 mmol). After a usual work-up, the residue was chromatographed on silica gel (hexane/AcOEt, 3:1). The first eluate gave **17**[14] (5 mg, 5%) as an oil; IR ($CHCl_3$) cm^{-1}: 1650; ^1H NMR (500 MHz, $CDCl_3$) δ: 1.35 (3H, d, J=6.8 Hz), 1.56-1.63 (1H, m), 2.20-2.30 (2H, m), 2.37-2.45 (1H, m), 2.99-3.07 (1H, m), 3.34 (3H, s), 7.16-7.31 (4H, m); ^{13}C NMR (125 MHz, $CDCl_3$) δ: 17.8, 32.6, 33.5, 35.1, 37.5, 122.3, 125.2, 126.2, 127.0, 138.6, 143.5, 173.4. The second eluate gave **15** (11 mg, 10%) as an oil. The third eluate gave **16**[11] (34 mg, 36%) as colorless crystals; mp 95.5-96.5 °C (from hexane), lit.[11] 96-97 °C (from hexane); IR ($CHCl_3$) cm^{-1}: 1660; ^1H NMR (500 MHz, $CDCl_3$) δ: 1.97 (3H, s), 3.24 (2H, br), 3.49 (3H, s), 5.69 (1H, s), 7.09-7.28 (4H, m); ^{13}C NMR (125 MHz, $CDCl_3$) δ: 24.3, 36.6, 38.0, 120.0, 121.6, 125.1, 127.2, 127.3, 135.5, 141.8, 152.8, 167.4.

***N*-Benzyl-*N*-[2,2-bis(phenylthio)ethenyl]trichloroacetamide (18).** To a solution of 2,2-bis(phenylthio)acetaldehyde[15] (1.44 g, 5.33 mmol) in Et_2O (30 mL) were added benzylamine (0.6 mL, 5.33 mmol) and $MgSO_4$ (10 g), and the mixture was stirred at room temperature for 3 h. The reaction mixture was filtered and the filtrate was concentrated. To a solution of this residue in toluene (50 mL) were added trichloroacetyl chloride (0.93 mL, 8.3 mmol) and *N,N*-diethylaniline (1.76 ml, 11.06 mmol) and the mixture was heated under reflux for 2 h. The reaction mixture was diluted with water and extracted with AcOEt. The extract was washed with brine, dried ($MgSO_4$), and concentrated. The residue was chromatographed on silica gel (hexane/AcOEt, 60:1→30:1) to give **18** (2.18 g, 80%) as an oil; IR ($CHCl_3$) cm^{-1}: 1685; ^1H NMR (270 MHz, $CDCl_3$) δ: 5.12 (2H, s), 6.87 (1H, s), 7.05-7.39 (15H, m); ^{13}C NMR (125 MHz, $CDCl_3$) δ: 54.0, 92.9, 127.9, 128.0, 128.2, 128.4, 128.71, 128.73, 128.9. 129.8, 130.5, 131.8, 132.5, 133.3, 135.1, 135.9, 160.4; HRMS Calcd for $C_{23}H_{18}Cl_3NOS_2$: 492.9896, found: 492.9893.

***N*-Benzyl-*N*-[2,2-bis(phenylthio)ethenyl]dichloroacetamide (19).** A solution of compound **18** (49.5 mg, 0.1 mmol) in 1,4-dimethylpiperazine (5 mL) was heated at reflux for 30 min. After a work-up similar to that described above for **4**, the residue was chromatographed on silica gel (hexane/AcOEt, 30:1→10:1) to give **19** (12 mg, 26%) as an oil; IR ($CHCl_3$) cm^{-1}: 1690; ^1H NMR (500 MHz, $CDCl_3$) δ: 4.81 (2H, s), 6.24 (1H, s), 6.36 (1H, br s), 7.08-7.44 (15H, m); ^{13}C-NMR (125 MHz, $CDCl_3$) δ: 51.1, 65.1, 126.7, 127.9, 128.4, 128.7, 128.9, 129.1, 129.7, 131.6, 132.3, 133.8, 135.5, 139.6, 163.5; HRMS Calcd for $C_{23}H_{19}Cl_2NOS_2$: 459.0285, found: 459.0280.

1-Benzyl-3-chloro-2-oxo-4-phenylthio-3-pyrroline (20). Using a procedure similar to that described above for the preparation of **5** and **6**, compound **18** (1.34 g, 2.71 mmol) was treated twice with AIBN (89 mg, 0.54 mmol) and Bu_3SnH (867 mg, 2.98 mmol). After a usual work-up, the residue was chromatographed on silica gel (hexane/AcOEt, 10:1→5:1→3:1) to give **20** (154

mg, 18%) as colorless crystals; mp 38-39 °C; IR ($CHCl_3$) cm^{-1}: 1695; ^1H NMR (500 MHz, $CDCl_3$) δ: 3.53 (2H, s), 4.55 (2H, s), 7.14 (2H, d, J=6.7 Hz), 7.23-7.50 (8H, m); ^{13}C NMR (125 MHz, $CDCl_3$) δ: 46.9, 51.6, 121.1, 127.3, 127.68, 127.75, 128.7, 129.8, 130.0, 134.7, 136.4, 146.7, 165.2; HRMS Calcd for $C_{17}H_{14}ClNOS$: 315.0485, found: 315.0491.

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