Synthesis of the First Examples of 1-Benzotellurepines and 1-Benzoselenepines

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The novel 2-alkyl-1-benzotellurepines **8** and 2-alkyl-1-benzoselenepines **9** have been obtained by sodium borohydride reduction of the ditelluride **4** and diselenide dimers **5**, prepared from 4-alkyl-1-(*o*-bromophenyl)but-1-en-3-ynes **3** *via* three steps in one pot, together with the 2-methylene-tellurachromenes **10** and -selenachromenes **11**, respectively, *via* the phenyl-selenol and -tellurol intermediates **6** and **7**.

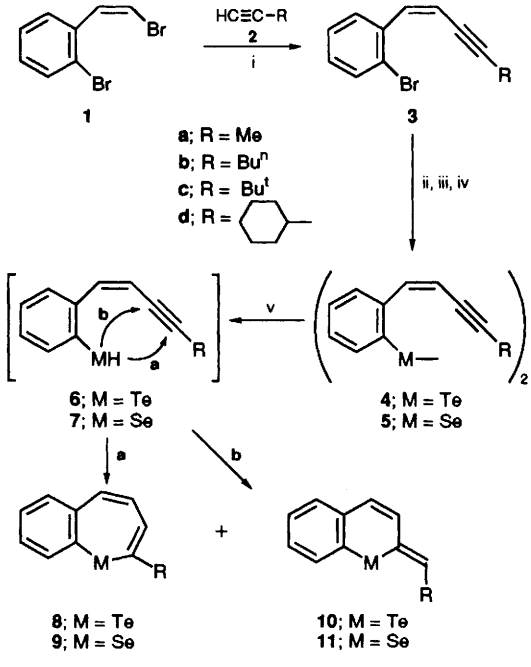
The synthesis of new fully unsaturated seven-membered heterocyclic rings (heteroepines) containing an element other than nitrogen, oxygen or sulfur has attracted much attention in recent years. With regard to the Group 16 heteroepines, a variety of oxepines[1] and thiepines[2–4] have been prepared; however, heteroepines containing heavier elements such as Te and Se have been predicted[5] to be more thermolabile than thiepines and only a limited number of examples of tellurepines and selenepines are known.[5–7] 4,5-Diethoxycarbonyl-2,7-di-*tert*-butylselenepine[5] is prepared by ring expansion of a 4*H*-selenapyran derivative and dibenzo[*b*,*f*]selenepine[6] is obtained from 2-(phenylseleno)benzoic acid *via* eight steps. More recently, the synthesis of 3-benzotellurepines from diethynylbenzene has been reported.[7] We report here on the first synthesis of 1-benzotellurepines and 1-benzoselenepines.

It is known that simple thiepines are thermally unstable owing to ready sulfur extrusion, but the stability of the thiepine ring can be enhanced by introduction of bulky groups in the α-positions.[2] For example, the half-life of 2-methyl-1-benzothiepines is more than twice as long as that of the parent 1-benzothiepine ($t_{1/2}$ = 58 min at 47 °C).[4] This finding on thiepines suggests that only 1-benzotellurepines and 1-benzoselenepines having at least one bulky group at the C-2 position could be isolated.

(*Z*)-*o*,β-Dibromostyrene **1**, prepared from *o*-bromobenzaldehyde,[8] was coupled[9] with the alkylacetylenes **2a–d** in the presence of a catalytic amount of a mixture of bis(triphenylphosphine)palladium dichloride and copper(I) iodide to give the corresponding 4-alkyl-1-(*o*-bromophenyl)but-1-en-3-ynes **3** in 80–95% yields.† The enynes **3** were lithiated with *tert*-butyllithium and then treated with Te or Se powder, followed by oxidation with potassium ferricyanide giving rise to the ditelluride **4** and diselenide dimers **5** in 60–70% yields in one pot.‡ Treatment of the dimers **4** and **5** with sodium borohydride in tetrahydrofuran–ethanol resulted in ring closure to give the desired 1-benzotellurepines **8** and 1-benzoselenepines **9**,§ together with the 2-methyleneheterochromenes **10** and **11**, respectively, probably *via* the intermediates **6** and **7**, which might undergo two competing paths for intramolecular cyclization; path **a** gives the seven-membered ring compounds **8** and **9** and path **b** affords the six-membered ring products **10** and **11**, as shown in Scheme 1.

It is known that the sodium borohydride reduction of diphenyl ditelluride[10] generated phenyltellurol *in situ*, which underwent stereospecific intermolecular *trans*-addition to phenylacetylene forming (*Z*)-phenyl styryl telluride.[11] This result clearly supports the present final reaction proceeding *via* the intermediates **6** and **7**, and thus the exocyclic methylene moiety in the chromenes **10** and **11** was tentatively assigned the (*Z*)-stereochemistry.¶ In addition, 2-alkyl-1-benzothiepines were also obtained by using sulfur powder instead of Te or Se powder.

As expected, the heteroepines **8c** and **9c** having the most bulky *tert*-butyl group are stable and can be kept for several weeks at room temperature even in solution, whereas the 2-methyl derivatives **8a** and **9a** are unstable and gradually



Scheme 1 *Reagents and conditions*: i, $[Pd(PPh_3)_2Cl_2]$, CuI, benzene–piperidine (1 : 1), 50–60 °C, 10–12 h; ii, Bu^tLi, tetrahydrofuran (THF), −80 °C, 1 h; iii, Te or Se powder, −40 °C to room temp., 1 h; iv, $K_3Fe(CN)_6$, room temp., 0.5 h; v, $NaBH_4$, THF–EtOH (1 : 1), 55 °C, 5–7 h

† Satisfactory elemental analyses and spectral (NMR, IR and mass) data were obtained for all new compounds reported. Selected data for **3**: **3a** b.p. 99 °C (3 mmHg); IR ν_{max}/cm^{-1} (neat) 2204; ^1H NMR (100 MHz, $CDCl_3$) δ 1.97 (3 H, d, *J* 2 Hz, Me), 5.77 (1 H, dq, *J* 12 and 2 Hz, β-H), 6.87 (1 H, d, *J* 12 Hz, α-H), 7.05–7.66 (3 H, m, Ph-H), 8.33 (1 H, dd, *J* 7 and 2 Hz, Ph-H). All compounds **3a–d** are pale yellows oils.

‡ All the dimers **4a–d** and **5a–d** are red oil. Selected data: **4a**, MS *m*/*z* 542 (M^+); IR ν_{max}/cm^{-1} (neat) 2200; ^1H NMR (100 MHz, $CDCl_3$) δ 1.97 (6 H, d, *J* 2 Hz, Me), 5.64 (2 H, dq, *J* 12 and 2 Hz, β-H), 6.74 (2 H, d, *J* 12 Hz, α-H), 6.80–7.80 (8 H, m, Ph-H).

§ Isolated yields of **8–11**: **8a** 8% and **10a** 5%; **8b** 22% and **10b** 15%; **8c** 60% and **10c** 17%; **8d** 20% and **10d** 51%; **9a** 2–3% and **11a** 2–3%; **9b** 11% and **11b** 10%; **9c** 34% and **11c** 45%; **9d** 9% and **11d** 66%. All compounds **8–11** are pale yellow oils except for **9d** (m.p. 83–85 °C) and **11d** (m.p. 50–52 °C). Selected ^1H NMR (400 MHz, $CDCl_3$): **8c** δ 1.21 (9 H, s, Bu^t), 6.33 (1 H, dd, *J* 12.5 and 5.5 Hz, 4-H), 6.58 (1 H, d, *J* 5.5 Hz, 3-H), 6.99 (1 H, d, *J* 12.5 Hz, 5-H), 7.19–7.30 (3 H, m, Ph-H), 7.76 (1 H, d, *J* 7.7 Hz, 9-H); **9c** δ 1.22 (9 H, s, Bu^t), 6.37 (1 H, dd, *J* 12.1 and 5.5 Hz, 4-H), 6.39 (1 H, d, *J* 5.5 Hz, 3-H), 6.99 (1 H, d, *J* 12.1 Hz, 5-H), 7.18–7.29 (3 H, m, Ph-H), 7.50 (1 H, d, *J* 6.6 Hz, 9-H); **10c** δ1.15 (9 H, s, Bu^t), 5.75 (1 H, d, *J* 11.4 Hz, 3-H), 6.12 (1 H, d, *J* 11.4 Hz, 4-H), 6.32 (1 H, s, =C*H*Bu^t), 6.93–7.05 (3 H, m, Ph-H), 7.33 (1 H, d, *J* 7.3 Hz, 8-H); **11c** δ 1.19 (9 H, s, Bu^t), 5.77 (1 H, s, =C*H*Bu^t), 6.00 (1 H, d, *J* 10.6 Hz, 3-H), 6.14 (1 H, d, *J* 10.6 Hz, 4-H), 6.98–7.04 (3 H, m, Ph-H), 7.17 (1 H, d, *J* 6.3 Hz, 8-H).

¶ It is known that treatment of phenyllithium with Te forms initially the unisolable phenyltellurol, which on treatment with an appropriate oxidizing agent gives the stable diphenyl ditelluride.[10] Therefore, in the present process **3** → **4**, the reaction mixture before oxidation can be assumed to involve the phenyltellurols **6**; thus treatment of the mixture with sodium borohydride and ethanol, but without oxidation, also afforded the products **8** and **10**, but in low yields.

decompose to 1-methylnaphthalene and Te or Se, by analogy with 1-[12] and 3-benzophosphepines,[13] 3-benzotellurepines[7] and 1-benzothiepines;[4] such decomposition causes the low isolated yields and is almost complete after 2–3 days at room temperature. The heterochromenes **10** and **11** are also thermolabile and gradually decompose to give complex mixtures.

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