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Evaluation of phenylorganotellurium compounds as radical precursors in dialkylzinc-mediated radical addition to C=N double bonds

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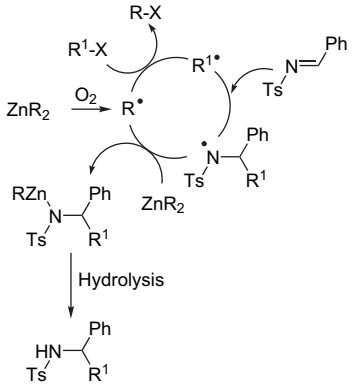
Abstract—Diethylzinc-mediated radical addition to C=N bonds was investigated in the presence of phenylorganotellurium compounds as radical precursors. As group transfer agents, secondary alkyl phenyl tellurides were shown to be about twice as reactive as the corresponding alkyl iodides towards ethyl radical. Their use was proven to be advantageous regarding both chemoselectivity and yield. The replacement of diethylzinc by dimethylzinc, offers no advantage in these reactions.

1. Introduction

The use of dialkylzinc as stoichiometric reagents to mediate radical addition to imino group has been developed by our group a few years ago.[1] Put together with the important contributions from the groups of Tomioka[2] and Naito,[3] these studies enable a comprehensive picture to be drawn for these reactions.[4,5] A general mechanistic scheme is given in Scheme 1.



Scheme 1. General mechanism (R=Me, Et; X=I, TePh).

The alkyl radical resulting from the reaction of the organometallic compound with oxygen undergoes atom or group transfer with the radical precursor R^1–X to generate radical $R^{1\bullet}$. The latter adds to the C=N bond, this leads to an aminyl radical likely to be complexed to Zn(II). Subsequent homolytic substitution at zinc results, after hydrolysis, in the formation of an amine. Most of these studies were carried out with diethylzinc as chain-transfer agent which implied the use of highly reactive radical precursors and thereby, all reactions involved alkyl iodides as radical precursors. The latter were generally used in large excess to avoid the competitive addition of ethyl radical. This is a limitation imposed on the methodology since only tertiary or secondary alkyl iodides that lead to exothermic iodine atom transfer to ethyl radical are appropriate radical precursors. Tomioka has recently pointed out that in this regard, the use of dimethylzinc inducing the formation of methyl radical could be advantageous. Methyl radical more reactive than ethyl radical with regard to iodine atom transfer enables the use of primary alkyl iodides as radical precursors.[2,6] We report in this article our brief investigation of the scope and limitation to the use of alkyl phenyl tellurides as radical precursors in these reactions.

Two excellent surveys of radical reactions involving organotellurium compounds have recently been published by Yamago,[7] and by Petragnani and Stefani,[8] respectively. The use of organotellurium compounds as precursors for carbon-centered radicals was first reported by Clive in 1980.[9] Since then, the radical chemistry of these compounds has been developed particularly in group transfer radical

Keywords: Alkyl phenyl telluride; Diethylzinc; Dimethylzinc; Radical addition to imino group.
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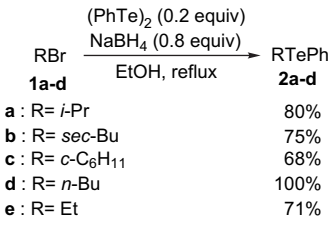
additions.[7,8,10] Kinetic studies have demonstrated that phenyl tellurides leading to carbethoxymethyl radical were as reactive as the corresponding iodides with respect to the transfer of phenyltellanyl-group to *n*-octyl radical at 50 °C.[11] The transfer of phenyltellanyl-group to vinyl radical was shown to be 10 times as fast as the iodine atom transfer from studies of radical addition to alkynes.[12] The rate constant for the transfer of methyltellanyl-group was determined four times superior to that of iodine in living radical polymerization of styrene at 60 °C.[13] Kim's report on radical additions to methanesulfonyl oxime ethers is particularly relevant to our studies.[14] In these reactions primary alkyl phenyl tellurides were shown from competitive experiments to be more than 18 times more reactive than primary alkyl iodides with regard to methyl radical at 140 °C. The temptation was great to investigate the synthetic potential of these precursors in dialkylzinc-mediated radical additions.

2. Results and discussion

Primary and secondary phenylorganotellurium compounds were prepared according to a known procedure by treating the corresponding alkyl bromide with $(PhTe)_2$ and sodium borohydride in ethanol.[9,15] Yields varied from 68 to 80% for secondary alkyl phenyl tellurides; *n*-butyl bromide and ethyl bromide were transformed into the corresponding primary alkyl phenyl telluride in good yields (Scheme 2). Attempts to prepare tertiary phenylorganotellurium compounds by this methodology were unsuccessful. Other methodologies were reported to give low yields in tertiary alkyl derivatives.[16]

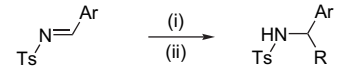


Scheme 2. Preparation of alkyl phenyl tellurides.

The reactions were first conducted on tosylimines **3**–**5** (Table 1). These imines were prepared by heating the appropriate aldehyde and *p*-toluenesulfonamide in the presence of tetraethyl orthosilicate.[17] The experiments were initially carried out by adding Et_2Zn (1 M solution in hexanes) to a solution containing the tosylimine and **2a**–**e** in dichloromethane under inert atmosphere. Air was then injected throughout the solution (generally over 1 h). The resulting mixture was stirred for two additional hours before treatment.

As indicated in Table 1, in the experiments conducted on tosylimine **3** using secondary alkyl phenyl tellurides as radical precursors (entries 1–4), 5 equiv of compounds **2a**, **2b**, or **2c** were necessary to completely suppress the competitive addition of ethyl radical formed in the initiation step (Scheme 1). The desired adducts were isolated in yields ranging from 68 to 75%. The addition to substituted phenyl tosylimines **4** and **5** gave similar results (entries 5 and 6). The lower yield registered for imine **4** is not surprising since the electron-donating effect of the *p*-methoxy group makes the C=N double bond less reactive with regard to nucleophilic alkyl radicals.

Table 1. Dialkylzinc-mediated addition of alkyl radicals generated from **2a**–**e** to tosylimines **3**–**5**



3 Ar = Ph **6** Ar = Ph
4 Ar = *p*-OMePh **7** Ar = *p*-OMePh
5 Ar = *p*-COOMePh **8** Ar = *p*-COOMePh

Entry	In.	**3**–**5**	R	Product	%[a]
1	$ZnEt_2$	**3**	*i*-Pr	**6a**	75
2	BEt_3	**3**	*i*-Pr	**6a**	21[b]
3	$ZnEt_2$	**3**	*sec*-Bu	**6b**	75
4	$ZnEt_2$	**3**	*c*-C_6H_{11}	**6c**	68
5	$ZnEt_2$	**4**	*i*-Pr	**7a**	55
6	$ZnEt_2$	**5**	*i*-Pr	**8a**	79
7	$ZnMe_2$	**3**	*i*-Pr	**6a**	3
8	$ZnMe_2$	**3**	*i*-Pr	**6a**	20[c]
9	$ZnMe_2$	**3**	*i*-Pr	**6a**	43[d]
10	$ZnEt_2$	**3**	Et	**6e**	56
11	$ZnEt_2$	**3**	Et	**6e**	83[e]
12	$ZnEt_2$	**3**	*n*-Bu	**6d**	—[f]
13	$ZnMe_2$	**3**	*n*-Bu	**6d**	—[g,h]
14	$ZnMe_2$	**3**	Et	**6e**	—[g]

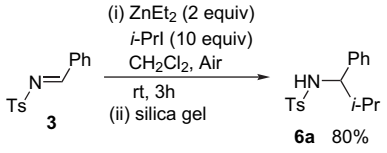
(i) Initiator (In.) (2 equiv), **2a–e** (5 equiv), CH_2Cl_2, air, rt, 3 h unless otherwise stated, (ii) silica gel.
[a] Isolated yield.
[b] Starting material (77%) was recovered using 3 equiv of BEt_3.
[c] $ZnMe_2$ (5 equiv), 3 h.
[d] $ZnMe_2$ (5 equiv), 18 h; pursuing the reaction for 3 days did not improve the yield.
[e] Et_2Zn (5 equiv), 18 h.
[f] Only the adduct of ethyl radical was detected by ^1H NMR.
[g] Tosyl amide was quantitatively recovered after hydrolysis of the starting material even with 10 equiv of $ZnMe_2$.
[h] $ZnMe_2$ (5 equiv), $BF_3{\cdot}OEt_2$ (5 equiv) and $Cu(OTf)_2$ (0.1 equiv).

It is to be noted that the reaction mediated with triethylborane instead of diethylzinc was dramatically slower since in this case, only 21% of the desired adduct was isolated after 3 h. Up to 77% of the starting material remained unchanged, and was recovered as tosyl amide after treatment with silica gel (entry 2, footnote b). This is likely to reflect the compared aptitude of diethylzinc and triethylborane, as Lewis acids, to activate the reactivity of the imino group.

The reaction was also far slower when using dimethylzinc instead of diethylzinc, since 5 equiv of this mediator and overall stirring for 18 h were necessary to reach 43% yield in **6a** (entries 7–9, footnotes c and d). The low efficiency of dimethylzinc compared to diethylzinc can be correlated to its lower oxidation rate, which necessitates prolonged exposure to oxygen. Moreover, from the reactivity studies reported herein, it seems that dimethylzinc and diethylzinc (or the oxygenated species formed during their oxidation) behave differently in their capacity, as Lewis acids, to activate the reactivity of the imino group through complexation.

In order to compare the reactivity of secondary alkyl phenyl tellurides to secondary alkyl iodides in diethylzinc-mediated radical addition to tosylimines, **6a** was prepared by replacing **2a** by iso-propyl iodide (Scheme 3). In this case, 10 equiv of radical precursor was needed to completely avoid the

competitive addition of ethyl radical. This result suggests that secondary alkyl phenyl tellurides are roughly twice as reactive as the corresponding alkyl iodides towards ethyl radical at room temperature.



Scheme 3. Use of isopropyl iodide as radical precursor.

Regarding the addition of primary alkyl radicals, it must be noted that, in the absence of alkyl phenyl telluride, the addition of ethyl radical to imine **3** led to **6e** isolated in only 56% yield (entry 10). The primary alkyl radicals, less nucleophilic than secondary ones, are less reactive with regard to addition to the imino group. The use of up to 5 equiv of diethylzinc and stirring for 18 h at room temperature were necessary to reach 83% yield in the corresponding tosyl amide (Table 1, entry 11, footnote e).

Attempts to use *n*-butyl phenyl telluride (**2d**) as radical precursor failed (Table 1, entry 12). The ^{1}H NMR spectrum of the crude reaction mixture showed the presence of ethyl radical adduct in trace amount, but no addition of *n*-butyl radical was detected under these conditions.[18]

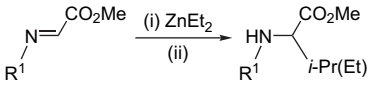
The use of dimethylzinc in the presence of primary alkyl phenyl tellurides **2d** and **2e** did not give the desired adduct. The starting material was quantitatively recovered under standard conditions (entries 13 and 14). This result was not surprising since it was shown by Tomioka that dimethylzinc-mediated addition of primary alkyl radical to tosylimines needed additional Lewis acids ($BF_3{\cdot}OEt_2$ and $Cu(OTf)_2$).[2g,19,20]

Such a procedure involving an additional activation with Lewis acids is not appropriate to perform the diethylzinc-mediated addition of primary alkyl radicals, since it would increase the rate of the competitive addition of ethyl radical. In the case of dimethylzinc, the use of additional Lewis acids might be appropriate since the addition of methyl radical does not compete with the addition of primary alkyl radicals.[2g] Unfortunately, no product resulting from the addition of butyl radical was detected even in the presence of $BF_3{\cdot}OEt_2$ and $Cu(OTf)_2$ (entry 13, footnote h). It seems that primary alkyl phenyl tellurides do not behave like the corresponding iodides towards dimethylzinc-mediated radical addition to tosylimines.

The reactivity of more reactive glyoxylic C=N bonds was then investigated. The reactions were conducted on imine **9** and hydrazone **10**. The latter were prepared according to known procedures by mixing methylglyoxylate with phenethylamine and diphenylhydrazine, respectively.[1b]

For comparison sake all experiments were performed under similar conditions regarding temperature and time of reaction. The results of diethylzinc-mediated reactions are reported in Table 2, those obtained with dimethylzinc are given in Table 3. In the case of the chiral imine **9**, owing to the creation of a second stereogenic centre, the adducts were isolated as mixture of two diastereomers.[21,1a]

Table 2. Diethylzinc-mediated addition of isopropyl radical to glyoxylic C=N bonds



9 R^1 = $CH(CH_3)Ph$ **11a(b)**

10 R^1 = NPh_2 **12a(b)**

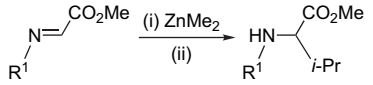
Entry	**9** and **10**	*i*-PrX	%[a]	**11** and **12** (**a**[dr]:**b**)
1	**9**	*i*-PrI	49	**11** (73[43:57]:27)
2	**9**	*i*-PrTePh	92	**11** (90[43:57]:10)
3	**10**	*i*-PrI	92	**12** (76:34)
4	**10**	*i*-PrTePh	70	**12** (100:0)
5	**10**	*i*-PrTePh	79[b]	**12** (93:7)

(i) $ZnEt_2$ (1.5 equiv), *i*-PrX (5 equiv), CH_2Cl_2, air, rt, 3 h unless otherwise stated, (ii) silica gel.
[a] Isolated yield.
[b] *i*-PrTePh (4 equiv).

As compared to the corresponding iodide, isopropyl phenyl telluride (**2a**) revealed itself to be a far better radical precursor. This was well demonstrated by the increase in chemoselectivity. The **11a**:**11b** ratio varied from 73:27 in entry 1 to 90:10 in entry 2. In addition the **12a**:**12b** ratio varied from 76:34 in entry 3 to 100:0 in entry 4. These ratios measure the competition between the addition of ethyl radical to the C=N double bond (a constant for each substrate) and the transfer of either phenyltellanyl-group or iodine atom to ethyl radical. In the presence of 5 equiv of **2a**, the competitive addition of ethyl radical was roughly divided by three in the case of imine **9**. No trace of ethyl radical adduct **12b** was detected in the case of hydrazone **10**. It is noteworthy that the overall yield was far superior when **2a** was used as radical precursor instead of *i*-PrI in the case of imine **9**.

Diphenyl hydrazone **10** is known to be a better alkyl radical acceptor than imine **9** in diethylzinc-mediated reactions.[1b,22] On this basis, one would expect chemoselectivity to be lower

Table 3. Dimethylzinc-mediated addition of isopropyl radical to glyoxylic C=N bonds



9 R^1 = $CH(CH_3)Ph$ **11a**

10 R^1 = NPh_2 **12a**

Entry	**9** and **10**	*i*-PrX	%[a]	**11** and **12** [dr]
1	**9**	*i*-PrI	27	**11a** [59:41]
2	**9**	*i*-PrTePh	76	**11a** [64:36]
3	**9**	*i*-PrTePh	88[b]	**11a** [64:36]
4	**10**	*i*-PrI	—[c]	**12a**
5	**10**	*i*-PrTePh	—[c]	**12a**

(i) $ZnMe_2$ (2 equiv), *i*-PrX (5 equiv), CH_2Cl_2, air, rt, 3 h unless otherwise stated, (ii) silica gel.
[a] Isolated yield.
[b] *i*-PrTePh (4 equiv).
[c] Compound **10** was quantitatively recovered.

in entry 4 than in entry 2. The reverse trend was observed, this strongly suggests that as far as tellurides are concerned, the radical reaction may not involve a completely 'free' alkyl radical species. This is in good agreement with the suggestion made by Schiesser that hypervalent Te(III) radical intermediates are involved in the transfer of RTe groups.[23]

Owing to the lack of reactivity of methyl radical, dimethylzinc avoids any trouble with chemoselectivity and the number of equivalents of radical precursor could be lowered when 2 equiv of this mediator was used (Table 3, entries 2/3).

Again the secondary telluride revealed itself to be far superior to *i*-PrI regarding the overall yield (entries 1/2). However, much to our surprise, hydrazone **10** did not lead to any adduct, neither with the secondary iodide, nor with the corresponding telluride (entries 4 and 5) as if **10** was not at all reactive as radical trap. Put together with the reversal of the diastereomeric ratio observed for adducts **11a** (43:57 with $ZnEt_2$/64:36 with $ZnMe_2$) these observations led us to the conviction that diethylzinc and dimethylzinc do not behave similarly as Lewis acids. The latter (or at least its derived species that might be alkoxy- or peroxyalkylzinc derivatives[24]) is not as good a Lewis acid as the former.

Much remains to be elucidated concerning the comparative properties of these two organometallic species. The subtle difference in their behaviours can be related to their reactivity with respect to oxidation.[25]

3. Conclusion

Diethylzinc-mediated radical addition to C=N bonds could be performed using phenylorganotellurium compounds as radical precursors. As group transfer agents, secondary alkyl phenyl tellurides were confirmed to be about twice as reactive as the corresponding alkyl iodides towards ethyl radical. Their use was proven to be advantageous compared to secondary iodides, regarding both chemoselectivity and yield. In these reactions, the use of dimethylzinc, more expensive than diethylzinc offers no advantage. The behaviour of primary phenylorganotellurium compounds in these reactions is not clearly understood yet.

4. Experimental section

4.1. General

NMR spectra were recorded at 300 MHz (^{1}H) and 75 MHz (^{13}C) using $CDCl_3$ as the solvent. The *J* values are given in hertz. Phenylorganotellurides **2a–e** were prepared according to known procedure.[9,15] Proton and carbon NMR are in accordance with those reported in the literature for **2a**,[26] **2b**,[27] **2c**,[28] **2d**,[26] **2e**.[26] Substrates **3–5**,[17] **9–10**[1b] were prepared according to known procedures.

4.2. General procedure for the radical addition

Method A: **2a–e** (5 equiv) was added under argon at room temperature, to a 0.2 M solution of substrate, in dichloromethane. Diethylzinc (2 or 5 equiv, 1 M solution in hexanes) was then introduced and the reaction was stirred at the same temperature while air (20 mL) was injected through a needle into the solution over 1 h. After stirring for 2 h at room temperature, the reaction was quenched by adding silica gel. After evaporation under reduce pressure, the crude product was purified by flash chromatography on silica gel (FC). *Method B*: triethylborane (3 equiv, 1 M solution in hexanes) was used instead of diethylzinc. *Method C*: dimethylzinc (2 or 5 equiv, 2 M solution in toluene) was used instead of diethylzinc.

4.2.1. 4-Methyl-*N*-(2-methyl-1-phenyl-propyl)-benzenesulfonamide (6a). Treating **3** (0.154 mmol, 40 mg) according to method A in the presence of **2a** (0.772 mmol, 191 mg) led after purification on silica gel (0–100% AcOEt/pentane) to **6a** (35 mg, 0.116 mmol, 75%).

Treating **3** (0.154 mmol, 40 mg) according to method B in the presence of **2a** (0.772 mmol, 191 mg) led after purification on silica gel (0–100% AcOEt/pentane) to **6a** (10 mg, 0.032 mmol, 21%).

Treating **3** (0.200 mmol, 52 mg) according to method C ($ZnMe_2$, 5 equiv) in the presence of **2a** (1.003 mmol, 247 mg) led after 18 h reaction followed by purification on silica gel (0–100% AcOEt/pentane) to **6a** (26 mg, 0.086 mmol, 43%). ^{1}H and ^{13}C NMR were in accordance with those reported in the literature.[29]

4.2.2. 4-Methyl-*N*-(2-methyl-1-phenyl-butyl)-benzenesulfonamide (6b). Treating **3** (0.154 mmol, 40 mg) according to method A in the presence of **2b** (0.772 mmol, 202 mg) led after purification on silica gel (0–100% AcOEt/pentane) to **6b** (36 mg, 0.115 mmol, 75%) as a 1:1 mixture of diastereoisomers. ^{1}H and ^{13}C NMR were in accordance with those reported in the literature.[30]

4.2.3. *N*-(Cyclohexyl-phenyl-methyl)-4-methyl-benzenesulfonamide (6c). Treating **3** (0.154 mmol, 40 mg) according to method A in the presence of **2c** (0.772 mmol, 225 mg) led after purification on silica gel (0–100% AcOEt/pentane) to **6c** (36 mg, 0.105 mmol, 68%). ^{1}H and ^{13}C NMR were in accordance with those reported in the literature.[2g]

4.2.4. 4-Methyl-*N*-(1-phenyl-propyl)-benzenesulfonamide (6e). Treating **3** (0.386 mmol, 100 mg) according to method A in the absence of other radical precursor led after purification on silica gel (0–100% AcOEt/pentane) to **6e** (63 mg, 0.218 mmol, 56%).

Treating **3** (0.386 mmol, 100 mg) according to method A ($ZnEt_2$, 5 equiv) in the absence of other radical precursor led after 18 h reaction followed by purification on silica gel (0–100% AcOEt/pentane) to **6e** (92 mg, 0.320 mmol, 83%). ^{1}H and ^{13}C NMR were in accordance with those reported in the literature.[31]

4.2.5. *N*-[1-(4-Methoxy-phenyl)-2-methyl-propyl]-4-methyl-benzenesulfonamide (7a). Treating **4** (0.149 mmol, 43 mg) according to method A in the presence of **2a** (0.745 mmol, 185 mg) led after purification on silica gel (0–100% AcOEt/pentane) to **7a** (27 mg, 0.081 mmol,

55%). ^{1}H NMR ($CDCl_3$, 300 MHz): δ 0.71 (d, 3H, J=6.8), 0.93 (d, 3H, J=6.8), 1.89 (oct, 1H, J=6.9), 2.32 (s, 3H), 3.73 (s, 3H), 3.96 (t, 1H, J=7.9), 5.12 (d, 1H, J=8.1), 6.62 (d, 2H, J=8.8), 6.84 (d, 2H, J=8.8), 7.06 (d, 2H, J=8.3), 7.48 (d, 2H, J=8.3). ^{13}C NMR ($CDCl_3$, 75 MHz): δ 19.0 (CH_3), 19.2 (CH_3), 21.4 (CH_3), 34.4 (CH), 55.2 (CH_3), 63.7 (CH), 113.4 (CH), 127.0 (CH), 128.0 (CH), 129.1 (CH), 132.1 (C), 137.7 (C), 142.6 (C), 158.6 (C). Anal. Calcd for $C_{18}NSO_3H_{23}$: C, 64.84; N, 4.20; S, 9.61; H, 6.95. Found: C, 64.78; N, 4.17; S, 9.25; H, 7.25.

4.2.6. 4-[2-Methyl-1-(toluene-4-sulfonylamino)-propyl]-benzoic acid methyl ester (8a). Treating **5** (0.157 mmol, 50 mg) according to method A in the presence of **2a** (0.788 mmol, 195 mg) led after purification on silica gel (0–100% AcOEt/pentane) to **8a** (45 mg, 0.124 mmol, 79%). ^{1}H NMR ($CDCl_3$, 300 MHz): δ 0.73 (d, 3H, J=6.8), 0.94 (d, 3H, J=6.8), 1.94 (oct, 1H, J=6.9), 2.31 (s, 3H), 3.90 (s, 3H), 4.09 (dd, 1H, J=7.7 and 7.9), 5.63 (d, 1H, J=8.5), 7.05 (d, 4H, J=8.1), 7.50 (d, 2H, J=8.3), 7.78 (d, 2H, J=8.3). ^{13}C NMR ($CDCl_3$, 75 MHz): δ 18.6 (CH_3), 19.3 (CH_3), 21.3 (CH_3), 34.2 (CH), 52.0 (CH_3), 63.8 (CH), 126.9 (CH), 127.0 (CH), 128.8 (C), 129.2 (CH), 129.3 (CH), 137.4 (C), 143.0 (C), 145.2 (C), 166.7 (C=O). Anal. Calcd for $C_{19}NSO_4H_{23}$: C, 63.14; N, 3.88; S, 8.87; H, 6.41. Found: C, 63.13; N, 3.80; S, 8.41; H, 6.48.

4.2.7. 3-Methyl-2-(1-phenyl-ethylamino)-butyric acid methyl ester (11a) and 2-(1-phenyl-ethylamino)-butyric acid methyl ester (11b). Treating **9** (0.2 mmol, 38 mg) according to method A ($ZnEt_2$, 1.5 equiv) in the presence of **2a** (1 mmol, 247 mg) led after purification on silica gel (0–100% AcOEt/pentane) to **11a** (40 mg, 0.17 mmol, 83%, 43:57 mixture of isomers) and **11b** (4 mg, 0.018 mmol, 9%, mixture of isomers).

Treating **9** (0.2 mmol, 38 mg) according to method A ($ZnEt_2$, 1.5 equiv) in the presence of *i*-PrI (1 mmol, 100 μL) led after purification on silica gel (0–100% AcOEt/pentane) to **11a** (16.7 mg, 0.071 mmol, 36%, 43:57 mixture of isomers) and **11b** (6 mg, 0.026 mmol, 13%, mixture of isomers).

Treating **9** (0.2 mmol, 38 mg) according to method C ($ZnMe_2$, 2 equiv) in the presence of **2a** (1 mmol, 247 mg) led after purification on silica gel (0–100% AcOEt/pentane) to **11a** (35.8 mg, 0.152 mmol, 76%, 64:36 mixture of isomers).

Treating **9** (0.2 mmol, 38 mg) according to method C ($ZnMe_2$, 2 equiv) in the presence of **2a** (0.79 mmol, 197 mg) led after purification on silica gel (0–100% AcOEt/pentane) to **11a** (41.3 mg, 0.175 mmol, 88%, 64:36 mixture of isomers).

Treating **9** (0.2 mmol, 38 mg) according to method C ($ZnMe_2$, 2 equiv) in the presence of *i*-PrI (1 mmol, 100 μL) led after purification on silica gel (0–100% AcOEt/pentane) to **11a** (12.6 mg, 0.054 mmol, 27%, 59:41 mixture of isomers). ^{1}H and ^{13}C NMR were in accordance with those reported in the literature for **11a**[32] and **11b**.[1b]

4.2.8. 2-(*N*′,*N*′-Diphenyl-hydrazino)-3-methyl-butyric acid methyl ester (12a) and 2-(*N*′,*N*′-Diphenyl-hydrazino)-butyric acid methyl ester (12b). Treating **10** (0.157 mmol, 40 mg) according to method A ($ZnEt_2$, 1.5 equiv) in the presence of **2a** (0.787 mmol, 195 mg) led after purification on silica gel (0–100% AcOEt/pentane) to **12a** (32.6 mg, 0.109 mmol, 70%).

Treating **10** (0.157 mmol, 40 mg) according to method A ($ZnEt_2$, 1.5 equiv) in the presence of **2a** (0.654 mmol, 162 mg) led after purification on silica gel (0–100% AcOEt/pentane) to **12a** (34.3 mg, 0.115 mmol, 73%) and **12b** (2.5 mg, 0.009 mmol, 6%).

Treating **10** (0.157 mmol, 40 mg) according to method A ($ZnEt_2$, 1.5 equiv) in the presence of *i*-PrI (0.817 mmol, 82 μL) led after purification on silica gel (0–100% AcOEt/pentane) to **12a** (32.5 mg, 0.109 mmol, 70%) and **12b** (9.7 mg, 0.034 mmol, 22%). ^{1}H and ^{13}C NMR were in accordance with those reported in the literature.[1b]

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References and notes

1. (a) Bertrand, M. P.; Feray, L.; Nouguier, R.; Perfetti, P. *Synlett* **1999**, 1148; (b) Bertrand, M. P.; Feray, L.; Nouguier, R.; Perfetti, P. *J. Org. Chem.* **1999**, *64*, 9189; (c) Bertrand, M. P.; Coantic, S.; Feray, L.; Nouguier, R.; Perfetti, P. *Tetrahedron* **2000**, *56*, 3951; (d) Bertrand, M. P.; Feray, L.; Gastaldi, S. *C. R. Chimie* **2002**, 623.
2. (a) Yamada, K.-I.; Fujihara, H.; Yamamoto, Y.; Miwa, Y.; Taga, T.; Tomioka, K. *Org. Lett.* **2002**, *4*, 3509; (b) Yamada, K.-I.; Yamamoto, Y.; Maekawa, M.; Tomioka, K. *J. Org. Chem.* **2004**, *69*, 1531; (c) Yamada, K.-I.; Yamamoto, Y.; Maekawa, M.; Chen, J.; Tomioka, K. *Tetrahedron Lett.* **2004**, *45*, 6595; (d) Yamada, K.-I.; Yamamoto, Y.; Tomioka, K. *Org. Lett.* **2003**, *5*, 1797; (e) Yamamoto, Y.; Yamada, K.-I.; Tomioka, K. *Tetrahedron Lett.* **2004**, *45*, 795; (f) Yamamoto, Y.; Maekawa, M.; Akindele, T.; Yamada, K.-I.; Tomioka, K. *Tetrahedron* **2005**, *61*, 379; (g) Yamada, K.-I.; Yamamoto, Y.; Maekawa, M.; Akindele, T.; Umeki, H.; Tomioka, K. *Org. Lett.* **2006**, *8*, 87; (h) Akindele, T.; Mamamoto, Y.; Maekawa, M.; Umeki, H.; Yamada, K.-I.; Tomioka, K. *Org. Lett.* **2006**, *8*, 5729.
3. (a) Miyabe, H.; Ueda, M.; Yoshioka, N.; Yamakawa, K.; Naito, T. *Tetrahedron* **2000**, *56*, 2413; (b) Miyabe, H.; Ushiro, C.; Ueda, M.; Yamakawa, K.; Naito, T. *J. Org. Chem.* **2000**, *65*, 176; (c) Miyabe, H.; Konishi, C.; Naito, T. *Org. Lett.* **2000**, *2*, 1443.
4. For a general review on dialkylzincs in radical chemistry, see: Bazin, S.; Feray, L.; Bertrand, M. P. *Chimia* **2006**, *60*, 260.
5. For reviews on radical addition to C=N bonds, see: (a) Friestad, G. *Tetrahedron* **2001**, *57*, 5461; (b) Friestad, G. *Eur. J. Org. Chem.* **2005**, 3157.
6. Dimethylzinc was also shown to be a convenient source of methyl radical in conjugate radical addition, see: Bazin, S.; Feray, L.; Vanthuyne, N.; Siri, D.; Bertrand, M. P. *Tetrahedron* **2007**, *63*, 77.

7. For a review on radical reactions involving organotellurium compounds, see: Yamago, S. *Synlett* **2004**, 1875.
8. For a more general review on organotelluriums chemistry, see: Petragnani, N.; Stefani, H. A. *Tetrahedron* **2005**, *61*, 1613.
9. Clive, D. L. J.; Chittattu, G. J.; Farina, V.; Kiel, W.; Menchen, S. M.; Russell, C. G.; Singh, A.; Wong, C. K.; Curtis, N. *J. Am. Chem. Soc.* **1980**, *102*, 4438.
10. For representative examples, see: (a) Crich, D.; Chen, C.; Wang, J.-T.; Yuan, H.; Papadatos, A.; Walter, R. I. *J. Am. Chem. Soc.* **1994**, *116*, 8937; (b) Engman, L.; Gupta, V. *J. Org. Chem.* **1997**, *62*, 157; (c) Yamago, S.; Miyazoe, H.; Yoshida, J. *Tetrahedron Lett.* **1999**, *40*, 2343; (d) Yamago, S.; Miyazoe, H.; Goto, R.; Hashidume, M.; Sawazaki, T.; Yoshida, J. *J. Am. Chem. Soc.* **2001**, *123*, 3697; (e) Kotani, M.; Yamago, S.; Satoh, A.; Tokuyama, H.; Fukuyama, T. *Synlett* **2005**, 1893; (f) Engman, L.; Laws, M. J.; Malmström, J.; Schiesser, C. H.; Zugaro, L. M. *J. Org. Chem.* **1999**, *64*, 6764.
11. (a) Curran, D. P.; Martin-Esker, A. A.; Ko, S.-B.; Newcomb, M. *J. Org. Chem.* **1993**, *58*, 4691; (b) Newcomb, M. *Tetrahedron* **1993**, *49*, 1151; (c) Russel, G. A.; Tashtoush, H. *J. Am. Chem. Soc.* **1983**, *105*, 1398.
12. Han, L.-B.; Ishihara, K.-I.; Kambe, N.; Ogawa, A.; Ryu, I.; Sonoda, N. *J. Am. Chem. Soc.* **1992**, *114*, 7591.
13. (a) Kwak, Y.; Goto, A.; Fukuda, T.; Kobayashi, Y.; Yamago, S. *Macromolecules* **2006**, *39*, 4671; (b) Goto, A.; Kwak, Y.; Fukuda, T.; Yamago, S.; Iida, K.; Nakajima, M.; Yoshida, J.-I. *J. Am. Chem. Soc.* **2003**, *125*, 8720.
14. Kim, S.; Song, H.-J.; Choi, T.-L.; Yoon, J.-Y. *Angew. Chem., Int. Ed.* **2001**, *40*, 2524.
15. Duddeck, H.; Biallaß, A. *Magn. Reson. Chem.* **1994**, *32*, 303.
16. Yamago, S.; Kazunori, I.; Yoshida, J.-I. *Tetrahedron Lett.* **2001**, *42*, 5061.
17. Love, B. E.; Raje, P. S.; Williams, T. C., II. *Synlett* **1994**, 493.
18. According to the mechanism proposed in Scheme 1, the reaction involves the transfer of the phenyltellanyl-group from R_1TePh to ethyl radical which leads to the corresponding ethyl phenyl telluride. In order to check if the phenyltellanyl-group was transferred in this case, **2d** was treated with 1 equiv of diethylzinc in undegassed CH_2Cl_2 for 18 h at room temperature. The ^{1}H NMR spectrum of the reaction mixture after filtration on a short pad of silica gel showed that EtTePh was formed in a 35:65 ratio with respect to **2d**. Unexpectedly, the ratio increased in degassed solution. It reached 45:55. When *i*-PrTePh (**2a**) was submitted to the same conditions, the formation of EtTePh was also dependent on the presence of oxygen, but the EtTePh:*i*-PrTePh ratio was 4:96 in degassed solution, and 25:75 in the presence of air. In the latter case, the Zn/Te exchange is in agreement with an oxygen-promoted radical mechanism. A spontaneous exchange proceeding via a non-radical mechanism might operate in the case of the primary phenyl telluride **2d**. Ni(acac)$_2$ was shown to catalyze tellurium-zinc exchange reactions. Both alkyl and phenyl groups could be transferred to zinc, see: Stüdemann, T.; Gupta, V.; Engman, L.; Knochel, P. *Tetrahedron Lett.* **1997**, *38*, 1005.
19. Contradictory reports have been published about the results of Ni(Acac)$_2$-catalyzed addition of diethylzinc to tosylimines, see: (a) Xiao, X.; Wang, H.; Huang, Z.; Yang, J.; Bian, X.; Qin, Y. *Org. Lett.* **2006**, *8*, 139; (b) Almansa, R.; Guijarro, D.; Yus, M. *Tetrahedron* **2007**, *63*, 1167. See also, Ref. 2g.
20. In situ reduction of Cu(II) and addition of an alkylcopper cannot be ruled out under these conditions.
21. The diastereomeric ratio could not be determined from the ^{1}H NMR of the crude product for ethyl radical adduct (**11b**) that was formed in small amount.
22. Kim, S.; Toon, K. S.; Kim, Y. S. *Tetrahedron* **1997**, *53*, 73.
23. (a) Schiesser, C. H.; Smart, B. A. *Tetrahedron* **1995**, *51*, 6051; (b) Schiesser, C. H.; Skidmore, M. A. *J. Organomet. Chem.* **1998**, *552*, 145; (c) Schiesser, C. H.; Wild, L. M. *J. Org. Chem.* **1999**, *64*, 1131.
24. Van der Deen, H.; Kellog, R. M.; Feringa, B. L. *Org. Lett.* **2000**, *39*, 925.
25. (a) Seyferth, D. *Organometallics* **2001**, *20*, 2940; (b) Lewinski, J.; Ochal, Z.; Bojarski, E.; Tratkiewicz, E.; Justyniak, I.; Lipkowski, J. *Angew. Chem., Int. Ed.* **2003**, *42*, 4643; (c) Lewinski, J.; Wojciech, M.; Lipkowski, J.; Justyniak, I. *J. Am. Chem. Soc.* **2003**, *125*, 12698; (d) Jana, S.; Berger, R. J.; Fröhlich, R.; Pape, T.; Mitzel, N. W. *Inorg. Chem.* **2007**, *46*, 4293.
26. Irgolic, K. J.; Busse, P. J.; Grigsby, R. A. *J. Organomet. Chem.* **1975**, *88*, 175.
27. For ^{125}Te NMR, see: Schiesser, C. H.; Skidmore, M. A. *Chem. Commun.* **1996**, 1419. ^{1}H NMR ($CDCl_3$, 300 MHz): δ 0.98 (t, 3H, J=7.4), 1.61 (d, 3H, J=7.2), 1.51–1.85 (AB part of ABX_3, 2H), 3.40 (sext, 1H, J=7.0), 7.22–7.37 (m, 3H), 7.82–7.85 (d, 2H, J=8.1).
28. Duddeck, H.; Wagner, P.; Biallaß, A. *Magn. Reson. Chem.* **1991**, *29*, 248.
29. Miyabe, H.; Ueda, M.; Nishimura, A.; Naito, T. *Tetrahedron* **2004**, *60*, 4227.
30. Miyabe, H.; Ueda, M.; Nishimura, A.; Naito. *Chem. Commun.* **2000**, 2059.
31. Zhang, J.; Yang, C.-G.; He, C. *J. Am. Chem. Soc.* **2006**, *128*, 1798.
32. Ikota, N.; Achiwa, K.; Yamada, S.-I. *Chem. Pharm. Bull.* **1983**, *31*, 887.