

# Carbonyl propargylation or allenylation by 3-haloprop-1-yne with tin(II) halides and tetrabutylammonium halides

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**3-Bromoprop-1-yne causes carbonyl propargylation with tin(II) chloride and tetrabutylammonium bromide in water to produce 1-substituted but-3-yn-1-ols, while 3-chloroprop-1-yne causes carbonyl allenylation with tin(II) iodide and tetrabutylammonium iodide in 1,3-dimethylimidazolidin-2-one to produce 1-substituted buta-2,3-dien-1-ols.**

Carbonyl propargylation or allenylation by 3-haloprop-1-yne with tin(II) chloride is one of the most convenient methods for introduction of propargyl (prop-2-ynyl) or allenyl functions.<sup>1–3</sup> The propargylation or allenylation is promoted by NaI or LiI; it has been presumed that the actual starting material, which reacts with tin(II) chloride, is 3-iodoprop-1-yne derived from the *in situ* reaction 3-bromoprop-1-yne with NaI or LiI.<sup>1,3</sup> We have found that carbonyl allylation by allylic acetates, allylic bromides, allylic chlorides and vinyl epoxides with tin(II) halide can be promoted by tetrabutylammonium bromide (TBABr).<sup>4–8</sup> A lack of reaction with TBABr might suggest that LiI is required to form the intermediate 3-iodoprop-1-yne.<sup>3</sup> Tetrabutylammonium halide (TBAX<sup>'''</sup>) probably reacts with tin(II) halide (SnX<sup>''</sup>) to form tetrabutylammonium trihalostannate, which is more nucleophilic than SnX<sup>''</sup>. We thus envisioned that TBAX<sup>'''</sup> would promote carbonyl propargylation or allenylation by 3-haloprop-1-yne with SnX<sup>''</sup>.<sup>9,10</sup> We here report that using different halogens in SnX<sup>''</sup> and TBAX<sup>'''</sup> affects the selectivity between carbonyl propargylation and allenylation by 3-haloprop-1-yne; carbonyl propargylation occurs with SnCl<sub>2</sub> and TBABr, while carbonyl allenylation occurs with SnI<sub>2</sub> and TBAI.

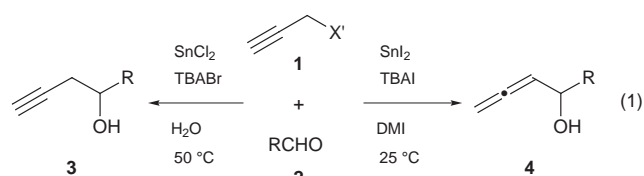
The reaction of 3-haloprop-1-yne **1** and benzaldehyde (**2**, R = Ph) with SnX<sup>''</sup> and TBAX<sup>'''</sup> was investigated under various

**Table 1** Propargylation and allenylation of **2** (R = Ph) with SnX<sup>''</sup> and TBAX<sup>'''</sup> <sup>a</sup>

Entry	X'	X''	TBA X''' (mmol)	Solvent	t/h	Yield (%) 3 + 4 <sup>b</sup>	5 <sup>c</sup>
1	Br	Cl	Br (1)	DMI	24	25 (100:0)	4
2	Br	Cl	Br (1)	THF	10	60 (100:0)	9
3	Br	Cl	Br (1)	THF–H <sub>2</sub> O <sup>d</sup>	8	70 (100:0)	8
4	Br	Cl	Br (1)	CH <sub>2</sub> Cl <sub>2</sub> –H <sub>2</sub> O <sup>d</sup>	8	58 (100:0)	12
5	Br	Cl	—	H <sub>2</sub> O	24	17 (100:0)	0
6	Br	Cl	Br (0.1)	H <sub>2</sub> O	8	61 (100:0)	13
7 <sup>e</sup>	Br	Cl	Br (0.3)	H <sub>2</sub> O	8	70 (100:0)	9
8	Br	Cl	Br (1)	H <sub>2</sub> O	7	72 (100:0)	10
9 <sup>f</sup>	Br	Cl	Br (1)	H <sub>2</sub> O	70	44 (100:0)	9
10	Br	Br	Br (1)	H <sub>2</sub> O	10	58 (100:0)	15
11 <sup>f,g</sup>	Cl	I	I (0.1)	THF	70	91 (31:69)	0
12 <sup>f,g</sup>	Cl	I	I (0.1)	DMF	28	91 (19:81)	0
13 <sup>f,g,h</sup>	Cl	I	I (0.1)	DMI	23	78 (4:96)	0
14 <sup>f,g</sup>	Cl	I	I (0.1)	DMI–H <sub>2</sub> O <sup>d</sup>	47	57 (33:67)	11

<sup>a</sup> The reaction of 3-haloprop-1-yne (1.5 mmol) and benzaldehyde (1.0 mmol) was carried out with SnX<sup>''</sup> (1.5 mmol) and TBA in solvent (3 ml) at 50 °C. <sup>b</sup> Yields of a mixture of **3** (R = Ph) and **4** (R = Ph). The ratio in parentheses was determined by <sup>1</sup>H NMR analysis (JEOL GX-270 or Λ-500). <sup>c</sup> Isolated yields of **5** (R = Ph). <sup>d</sup> Organic solvent–H<sub>2</sub>O = 1:1. <sup>e</sup> Method A. <sup>f</sup> The reaction was carried out at 25 °C. <sup>g</sup> NaI (1.5 mmol) was added. <sup>h</sup> Method B.

conditions. The results are summarized in Table 1. The reaction of 3-bromoprop-1-yne (**1**, X' = Br) with SnCl<sub>2</sub> and TBABr at 50 °C in water led to carbonyl propargylation to produce 1-phenylbut-3-yn-1-ol (**3**, R = Ph) (entry 7, Method A), while the reaction of 3-chloroprop-1-yne (**1**, X' = Cl) with SnI<sub>2</sub> and TBAI at 25 °C in 1,3-dimethylimidazolidin-2-one (DMI) led to carbonyl allenylation to produce 1-phenylbuta-2,3-dien-1-ol (**4**, R = Ph) (entry 13, Method B) [eqn. (1)]. TBAX<sup>'''</sup> accelerated

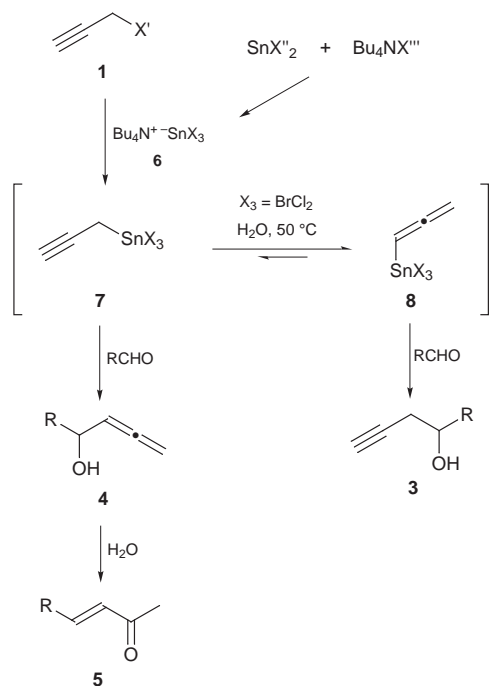


the carbonyl propargylation or allenylation; >0.1 equiv. of TBAX<sup>'''</sup> was required (entries 5–8). In the propargylation the use of SnCl<sub>2</sub> and TBABr (or TBACl) is superior to other combinations of reagents, while SnI<sub>2</sub>–TBAI is the best combination of reagents for the allenylation. 3-Chloroprop-1-yne (**1**, X' = Cl) did not react under the same conditions as those of the propargylation with **1** (X' = Br). Water is a more effective solvent in the propargylation than some organic polar solvents, such as DMI and THF, in which both organic substrates and SnCl<sub>2</sub> are soluble (entries 1, 2 and 8). The by-product produced during the propargylation, 4-phenylbut-3-en-2-one (**5**, R = Ph), was probably formed by the hydration of allenylated product **4** (R = Ph).<sup>3</sup> The reaction of **1** (X' = Cl) and **2** (R = Ph) with SnI<sub>2</sub>–TBAI did not occur in water, and proceeded with lower selectivity for the allenylation in DMI–water (entry 14). Thus, water is unsuitable for the allenylation, in which DMI is a better solvent than DMF or THF (entries 11–13).

**Table 2** Either propargylation or allenylation with SnX<sup>''</sup> and TBAX<sup>'''</sup>

R	Method <sup>a</sup>	t/h	Yield (%) 3 + 4 <sup>b</sup>	5 <sup>c</sup>
4-MeO <sub>2</sub> CC <sub>6</sub> H <sub>4</sub>	A	7	75 (100:0)	14
4-MeO <sub>2</sub> CC <sub>6</sub> H <sub>4</sub>	B	24	80 (17:83)	0
4-NCC <sub>6</sub> H <sub>4</sub>	A	16	77 (100:0)	4
4-NCC <sub>6</sub> H <sub>4</sub>	B	23	62 (2:98)	0
4-MeC <sub>6</sub> H <sub>4</sub>	A	20	70 (100:0)	4
4-MeC <sub>6</sub> H <sub>4</sub>	B	23	53 (7:93)	0
4-MeOC <sub>6</sub> H <sub>4</sub>	A	16	62 (100:0)	4
4-MeOC <sub>6</sub> H <sub>4</sub>	B	25	50 (5:95)	0
Me(CH <sub>2</sub> ) <sub>6</sub>	A	12	63 (100:0)	0
Me(CH <sub>2</sub> ) <sub>6</sub>	B	90 <sup>d</sup>	50 (7:93)	0
c-C <sub>6</sub> H <sub>11</sub>	A	12	48 (100:0)	7
c-C <sub>6</sub> H <sub>11</sub>	B	88 <sup>d</sup>	71 (20:80)	0

<sup>a</sup> Method A: Entry 7 in Table 1. Method B: Entry 13 in Table 1. <sup>b</sup> Yields of a mixture of **3** and **4**. The ratio in parentheses was determined by <sup>1</sup>H NMR analysis (JEOL GX-270 or Λ-500). <sup>c</sup> Isolated yields. <sup>d</sup> The reaction was carried out at 0 °C.



Scheme 1

The propargylation (Method A) and allenylation (Method B) of various aldehydes by 3-halo-1-yne **1** was carried out under the conditions which gave the best results for benzaldehyde, as summarized in Table 2. Aromatic aldehydes bearing an electron-donating or -withdrawing group and aliphatic aldehydes can be used to afford the corresponding 1-substituted but-3-yn-1-ols **3** using the  $\text{SnCl}_2$ -TBABr/water system or the corresponding 1-substituted buta-2,3-dien-1-ols **4** with the  $\text{SnI}_2$ -TBAI/DMI system in moderate yields.

A plausible mechanism was illustrated with Scheme 1. The difference between propargylation using the  $\text{SnCl}_2$ -TBABr/water system and allenylation using the  $\text{SnI}_2$ -TBAI/DMI system may be due to the Lewis acidity of the tin, reaction temperature and reaction medium.  $^1\text{H}$  NMR (JEOL  $\Lambda$ -500) observation in  $[\text{D}_2\text{H}_7]\text{DMF}$  at 25 °C revealed that prop-2-ynyltriiodotin (**7**,  $\text{X} = \text{I}$ ) was first formed *via* the reaction of

3-chloroprop-1-yne (**1**,  $\text{X}' = \text{Cl}$ ) with  $\text{SnI}_2$  and NaI. Prop-2-ynyltriiodotin (**7**,  $\text{X} = \text{I}$ ) probably proceeded *via*  $\gamma$ -addition to the aldehyde (carbonyl allenylation), without isomerizing to propa-1,2-dienyltriiodotin (**8**,  $\text{X} = \text{I}$ ), in dry polar solvents such as DMI and DMF to produce buta-2,3-dien-1-ols **4**.<sup>‡</sup> In contrast, the isomerization of prop-2-ynylbromodichlorotin (**7**,  $\text{X}_3 = \text{BrCl}_2$ ), derived from reaction of 3-bromoprop-1-yne (**1**,  $\text{X}' = \text{Br}$ ) with  $\text{SnCl}_2$  and TBABr at the organic-aqueous interface, to propa-1,2-dienylbromodichlorotin (**8**,  $\text{X}_3 = \text{BrCl}_2$ ) probably occurred more rapidly at 50 °C than carbonyl allenylation by **7** ( $\text{X}_3 = \text{BrCl}_2$ ).<sup>§</sup> The carbonyl propargylation by **8** ( $\text{X}_3 = \text{BrCl}_2$ ) at 50 °C in water thus produced but-3-yn-1-ols **3**.<sup>¶</sup>

## Notes and References

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<sup>‡</sup> The carbonyl allenylation by **7** ( $\text{X} = \text{I}$ ) seems to have proceeded *via* an acyclic antiperiplanar transition state, because of the weakly Lewis acidic tin in **7** ( $\text{X} = \text{I}$ ). See ref. 7 and 8.

<sup>§</sup> It was shown by  $^1\text{H}$  NMR analysis (JEOL  $\Lambda$ -500) that prop-2-ynyltriiodotin (**7**,  $\text{X} = \text{I}$ ), derived from 3-chloroprop-1-yne (**1**,  $\text{X}' = \text{Cl}$ ) *via* reaction with  $\text{SnI}_2$  and NaI in  $[\text{D}_2\text{H}_7]\text{DMF}$ , isomerized easily to propa-1,2-dienyltriiodotin (**8**,  $\text{X} = \text{I}$ ) at 50 °C; J. A. Marshall, R. H. Yu and J. F. Perkins, *J. Org. Chem.*, 1995, **60**, 5550.

<sup>¶</sup> The carbonyl propargylation by **8** ( $\text{X}_3 = \text{BrCl}_2$ ), which has a strongly Lewis acidic tin, seems to have proceeded *via* a usual six-membered cyclic transition state.

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