An Intriguing Hydroiodination of Alkenes and Alkynes with Titanium Tetraiodide

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Abstract: Olefins and acetylenes were hydroiodinated with titanium tetraiodide to give alkyl iodides, vinyl iodides, and alkyl diiodides in good yields. In the presence of acetals, the reaction gave intriguing C–C bond-forming products.

Key words: titanium tetraiodide, hydroiodination, alkene, alkyne, Prins reaction, alkyl iodide, alkyl diiodide

Hydrohalogenation reaction is one of the most fundamental yet important reactions in organic synthesis. Among them hydroiodination¹ of olefins and acetylenes provides alkyl and alkenyl iodides, which are important building blocks due to their high reactivity compared with their bromo and chloro counterparts. However, conventional methods using hydrogen iodide often suffer from low yields of products and side reactions.^{1a}

We have recently described useful reactions using titanium tetraiodide,² where the ability of titanium tetraiodide to iodinate and reduce organic molecules is responsible for the success of facile transformations. In an effort to utilize more effectively the iodination ability of titanium tetraiodide, we examined the hydroiodination reaction of olefins **1** and acetylenes **2** with titanium tetraiodides (Scheme 1). This paper describes a convenient method for the synthesis of alkyl and alkenyl iodides as well as alkyl diiodides, and intriguing Prins-type reactions promoted by titanium tetraiodide are also reported.



Scheme 1

Treatment of cyclododecene with TiI_4 (0.5 equiv) in CH_2Cl_2 at room temperature gave iodocyclododecane in 83% yield. Optimum reaction conditions were examined utilizing hydroiodination of cyclododecene, one equiva-

SYNLETT 2005, No. 16, pp 2516–2518 Advanced online publication: 06.09.2005 DOI: 10.1055/s-2005-872679; Art ID: U19905ST © Georg Thieme Verlag Stuttgart · New York lent of TiI₄ was found to give the best yield. Hydroiodination of a variety of olefins was carried out under optimum conditions and the results are summarized in Table $1.^3$

Cyclooctene (Table 1, entry 3) and (E)-6-dodecene (Table 1, entry 5) gave iodocyclooctane and 6-iodododecane in 51% and 54% yields, respectively, whereas only a trace amount of iodide was obtained from cyclohexene (Table 1, entry 4). Regarding the terminal olefins, 4-phenylbutene and styrene gave secondary iodinated products regioselectively in good yields (Table 1, entries 6 and 9). The presence of 4 Å molecular sieves did not noticeably alter the product yield, whereas the addition of water decreased the yield (Table 1, entries 7 and 8). Electronpoor olefins are not good substrates for the present hydroiodination, although diisopropyl succinate gave the desired product in 34% yield and the starting material was recovered in the case of chalcon (Table 1, entries 10 and 11). Tetrasubstitued olefin did not give the addition product (Table 1, entry 12). Furthermore, chloroiodination product 4 was observed when the reaction was carried out in the presence of NCS (Scheme 2).





When hydroiodination was carried out with alkynes, either hydroiodination or bis-hydroiodination was obtained depending on the substrates (Scheme 3). Phenylacetylene gave α -iodostyrene **5** in 59% yield, whereas bis-hydroiodinated products **6** were obtained from aliphatic counterparts. This selectivity may be explained by considering the instability of 1,1-diiodo-1-phenylethane, which on standing at room temperature under the present reaction conditions gave α -iodostyrene **5**.⁵ Furthermore, the internal acetylene **7** gave a mixture of vinyl iodide **8** and *gem*diiodinated compound **9** in 30% and 18% yields, respectively (Scheme 4).

Intriguing C–C bond-forming reactions were observed, when the hydroiodination reaction was carried out in the presence of acetals 10a-c (Schemes 5 and 6). Styrene 1aunderwent a Prins-type addition⁶ followed by iodination of the resulting methoxy species to give 1,3-diiodo deriv-

Table 1 Hydroiodination of Olefins^a

R ³ R ⁴	1) Til ₄ (1.0 equiv) CH ₂ Cl ₂ , r.t.	R^3
R ¹ R ²	2) H ₂ O	R ¹ β 3

Entry	\mathbf{R}^1	\mathbb{R}^2	R ³	\mathbb{R}^4	Time (h)	Yield (%) ^b
1 ^c	-(CH ₂) ₁₀ -		Н	H^{d}	19.0	83
2	-(CH ₂) ₁₀ -		Н	H^{d}	12.0	91
3	-(CH ₂) ₆ -		Н	Н	11.0	51
4	-(CH ₂) ₄ -		Н	Н	13.0	trace
5	C ₅ H ₁₁	Н	Н	C ₅ H ₁₁	12.0	54
6	Ph(CH ₂) ₂	Н	Н	Н	8.0	78
7 ^e	Ph(CH ₂) ₂	Н	Н	Н	12.0	74
8 ^f	$Ph(CH_2)_2$	Н	Н	Н	12.0	67
9	Ph	Н	Н	Н	12.0	53
10	<i>i</i> -PrO ₂ C	<i>i</i> -PrO ₂ C	Н	Н	8.0	34
11	PhCO	Н	Н	Ph	17.0	0
12	Me	Me	Me	Me	12.0	0

^a Reaction was carried out according to the typical procedure.^{3,}

^b Isolated yield.

^c TiI₄ (0.5 equiv) was used.

^d A mixture of E,Z isomers.

^e In the presence of rigorously dried 4 Å molecular sieves.

^f In the presence of 4 Å molecular sieves containing H₂O (1 equiv).⁴



Scheme 3



atives 11a,b as almost a 1:1 mixture of diastereomers in

good yield (Scheme 5). In the case of phenylacetylene

(2a), two equivalents of the acetal participated in the

addition reaction to give 1,4-diene 12 in good yield, where

the presence of a good leaving group resulted in high

Scheme 4

stereoselectivity (Scheme 6).⁷ These reactions are proposed to occur by the mechanisms shown in Schemes 5 and 6. So far, these types of reactions have been successfully carried out only with styrene and phenylacetylene derivatives, and we are currently investigating the scope of the reactions in more detail.

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Regarding the hydroiodination mechanism, we have not yet confirmed the possible intermediates **13** and **14** (Scheme 7) and we are currently trying to elucidate the in-





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termediates by spectral methods.⁸ For reactions with acetals, Prins-type intermediates may account for the facile C–C bond formations.⁷



Scheme 7

In conclusion, we have found that TiI_4 is a good reagent for hydroiodination of olefins and acetylenes. When the reactions were carried out in the presence of acetals, facile Prins-type C–C bond-forming reactions proceeded to give 1,3-diiodides from olefins and 1,5-diiodo-1,4-dienes from acetylenes.

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- (3) A typical procedure is as follows: To a suspension of TiI₄ (Soekawa Chemical Co., used after sublimation,^{2a} 111 mg, 0.20 mmol) in CH₂Cl₂ (1.0 mL) was added a solution of cyclododecene (33.3 mg, 0.20 mmol) in CH₂Cl₂ (1.0 mL) at r.t. After stirring at r.t. for 12 h, the reaction was quenched by the addition of sat. aq NaHCO₃ and aq NaHSO₃ (5%). The mixture was filtered through a Celite pad. The layers were separated and the aqueous layer was extracted with EtOAc (3×10 mL). The combined organic extracts were washed with sat. aq NaHCO₃ and brine, and then dried over anhyd Na₂SO₄. Purification by silica gel TLC (hexane) gave iodocyclododecane (53.8 mg, 91%) as a colorless oil.
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- (8) We have carried out several experiments quenching the reaction mixtures derived from alkenes or alkynes and TiI_4 with D_2O . However, little or no deuterium incorporation was observed.



Scheme 8

The reaction in CD₂Cl₂ also did not give the deuteriated product (vide supra). Elucidation of the intermediary species will be reported in due course.