Tetrahedron Letters, Vol. 33, No. 8, pp. 1037-1040, 1992
Printed in Great Britain

0040-4039/92 $3.00 + .00
Pergamon Press plc

A CONVENIENT PROCEDURE FOR THE DIRECT CONVERSION OF TERMINAL ALKENES INTO CARBOXYLIC ACIDS

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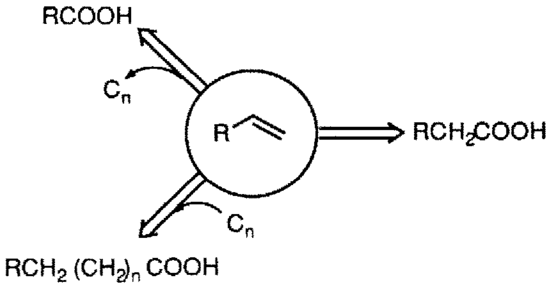
Summary: *Alkylboronic acids, readily synthesized from a variety of representative terminal alkenes via hydroboration with dibromoborane-methyl sulfide, undergo a facile oxidation with chromium trioxide in 90% aqueous acetic acid to provide carboxylic acids in 80-97% isolated yields, without rearrangement or loss of carbon.*

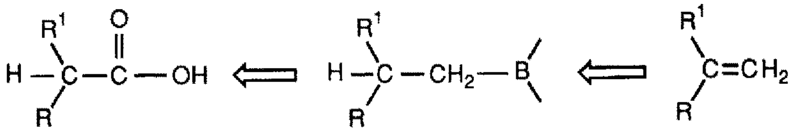
Carboxylic acids are a major class of organic compounds of exceptional importance in both organic synthesis and biology.[2] The synthesis of carboxylic acids from terminal alkenes via the oxidative cleavage of the carbon–carbon double bond and involving loss of carbon atom(s), is well established.[3] Many procedures are also available for the conversion of alkenes into carboxylic acids with an increased number of carbon atoms.[4] Interestingly, however, a preparatively useful direct synthesis of carboxylic acids from terminal alkenes without skeletal cleavage or rearrangement is not known (Scheme I).[5-7]

Scheme I



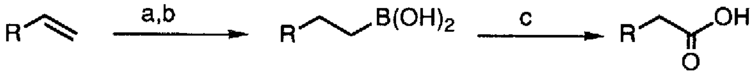
In the literature, a number of reagents are available for the efficient synthesis of carboxylic acids from primary alcohols.[8] Since the carbon–boron bond can serve as a masked synthon for the carbon–oxygen bond, we envisioned a simple direct synthesis of carboxylic acids from terminal olefins (Scheme II).

Scheme II



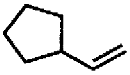
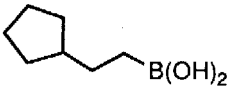
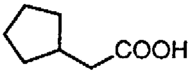
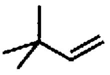
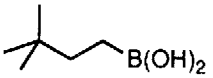
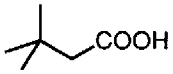
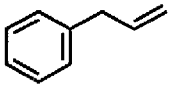
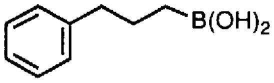
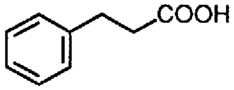
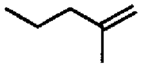
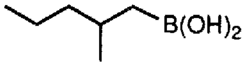
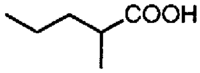
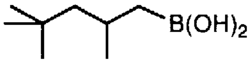
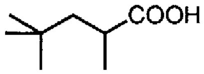
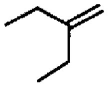
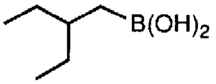
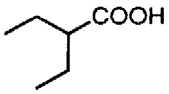
The oxidation of organoborane intermediates into alcohols, ketones, and aldehydes is well established.[9] However, the direct oxidation of organoboranes into carboxylic acids is unknown. The present communication reports, for the first time, the successful direct oxidation of representative alkylboronic acids with chromium trioxide (CrO_3) in 90% aqueous acetic acid to obtain carboxylic acids in excellent isolated yields (Scheme III, Table I).

Scheme III



(a) $HBBr_2.SMe_2$, 40 °C, CH_2Cl_2, 2 h; (b) H_2O, 25 °C, 0.5 h; (c) CrO_3, $AcOH/H_2O$, 25 °C, 12 h

Table I. Direct Synthesis of Carboxylic Acids From Olefins

olefin	boronic acid[a]	carboxylic acid	yield, %[b,c]
			97
			91
			80
			88
			94
			94
			92

(a) Synthesized in 90±5 % isolated yields (see ref.10). (b) Yields of isolated pure products.

(c) The products exhibited identical physical constants and spectral data as the authentic compounds.

In the past, we reported convenient experimental procedures for the synthesis of alkylboronic acids.[10] The following procedure is representative for the synthesis of carboxylic acids from the alkylboronic acids: To a burgundy colored solution of CrO_3 (5.99 g, 60 mmol) in a mixture of acetic acid (36 mL) and water (4 mL), a solution of *n*–hexylboronic acid[10] in CH_2Cl_2 (20 mL, 0.50 M, 10 mmoL) was slowly added[11] at 25 °C, and the reaction mixture was stirred for 12 h. The product was then diluted with water (20 mL) and extracted with CH_2Cl_2 (2x25 mL). The organic extract was washed with brine, followed by a saturated solution of $NaHCO_3$ (3x25 mL) to dissolve the acid. The bicarbonate extract was carefully acidified with conc. HCl until the pH of the solution became 1-3, and the mixture extracted with CH_2Cl_2 (2x25 mL). Finally, the organic extract was dried over Na_2SO_4 and the solvent removed under vacuum to obtain pure 1–hexanoic acid (1.13 g, 97 %).

As pointed out in Table I, the oxidation procedure works very well for a variety of representative olefins. CrO_3 is a polymer,[12] essentially insoluble in glacial acetic acid. However, it is highly soluble in acetic acid containing 10% (by weight) of water. Oxidation of alkylboronic acids with CrO_3 under this homogeneous condition is rapid and convenient. *Nevertheless, it must be pointed out that the oxidation of alkylboronic acids with CrO_3 can also be realized in glacial acetic acid (heterogeneous condition), at significantly slower reaction rates.*[13] Experimental studies also revealed that the stoichiometry of oxidation of alkylboronic acids with CrO_3 is as follows (eq.1):

$$RCH_2B(OH)_2 + 3\,CrO_3 + 12\,AcOH \longrightarrow RCOOH + B(OH)_3 + 3\,Cr(OAc)_4 + 6\,H_2O \quad (1)$$

On this basis, it appears that the oxidation of alkylboronic acids with CrO_3 in 90% acetic acid involves transfer of only two electrons ($Cr^{VI} \rightarrow Cr^{IV}$). Some examples of two electron oxidations with Cr^{VI} compounds have been reported in the past.[14] This is somewhat unusual considering that aqueous chromic acid oxidations generally invove three electron transfer.[5] Although the stoichiometry of the reaction calls for use of only 3 moles of oxidant per mole of substrate, we found that best results can be obtained by use of 6 moles (100 % excess) of the oxidant.

In conclusion, we have shown that organoboranes containing primary carbon–boron bond can directly serve as valuable intermediates in the synthesis of carboxylic acids from terminal alkenes. Furthermore, it appears that this oxidation procedure can also be extended to wide variety of other organoborane intermediates, such as outlined below:

$(RCH_2)_2BOH$

$(RCH_2)_3B$

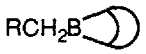
$RCH_2BBr_2.SMe_2$

$(RCH_2)_2BBr$

$(RCH_2)_2BCl$

$RCH_2B(Chx)_2$

RCH_2BSia_2



Presently, we are exploring the full scope of this new oxidation procedure utilizing a variety of olefins, and hydroborating agents. These results and the synthetic applications of this method will be reported in the near future.

Acknowledgement: We wish to thank the National Institutes of Health (GM 10937) for the financial support of this research.

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(1) (a) Research Scientist; (b) Post-doctoral Fellow on sabbatical leave from Ahmadnagar College, Ahmadnagar, India (1990-91).

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(13) *n*–Hexylboronic acid undergoes oxidation with CrO_3 in glacial acetic acid (25 °C, 0.5 h; 50 °C, 12 h) to provide 1–hexanoic acid in 92% isolated yield.

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(Received in USA 3 December 1991)