

SYNLETT Spotlight 83

This feature focuses on a reagent chosen by a postgraduate, highlighting the uses and preparation of the reagent in current research

Triethylborane (Et₃B)

Gavin O'Mahony

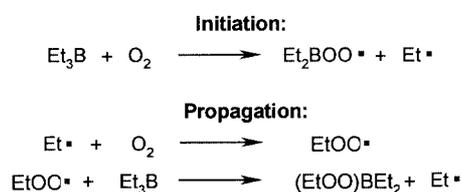
Gavin O'Mahony was born in Donegal, Ireland in 1980 and began studying chemistry at Queen's University Belfast in 1997. After receiving his B.Sc. in 2000, he joined the research group of Dr Paul J. Stevenson at Queen's and is currently undertaking a Ph.D. project in conjunction with CSS Ltd. as part of the CAST Award Scheme. His research is in palladium and ruthenium catalysed approaches to pumiliotoxin alkaloids.

School of Chemistry, Queen's University of Belfast, David Keir Building, Stranmillis Road, Belfast, BT9 5FS, Northern Ireland, UK



Introduction

Triethylborane is a colourless liquid that is spontaneously flammable in air, burning with a characteristic green flame. It is readily autoxidised by molecular oxygen via a radical mechanism (Scheme 1).



Scheme 1

This reactivity of triethylborane leads to one of its most common applications, i.e. as an initiator in radical reactions.

The first use of triethylborane as a radical initiator was reported in 1989 by Oshima.¹ Its main advantage is its effectiveness at low temperature (-78°C), which is useful in the case of stereoselective radical reactions^{2,3} or with thermally unstable reaction products. The use of AIBN, which forms radicals by thermal decomposition, is clearly not feasible in these cases, making triethylborane an attractive alternative. The use of organoboranes as a source of radicals has been recently reviewed.⁴ It has been extensively

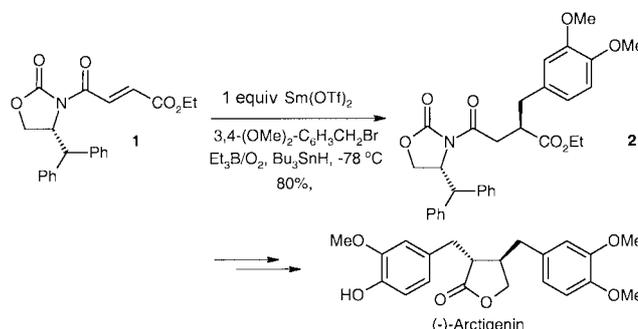
used in the development of tin-free radical chemistry, by-passing the tedious purification procedures often associated with the use of tin reagents.⁵⁻⁷ It has also been used in solid-supported radical C–C bond formation.⁸ Triethylborane has also been used in a novel one-pot cross-coupling of alkynes with aryl iodides to synthesise functionalised (*Z*)-arylalkenes from unprotected alkynes via a (*Z*)-alkenylindium species.⁹ Radical initiator-dependent reactivity has been noted in the three-component reaction of aldehydes, aryl amines and THF.¹⁰ Triethylborane can also be used as a radical initiator in both ionic liquids¹¹ and in aqueous systems.^{8,12}

Triethylborane has also found application in non-radical processes, such as promoting the palladium-catalysed allylation of active methylene compounds¹³ and amines¹⁴ with unactivated allylic alcohols and the triethylborane-triggered intermolecular domino three-component Michael-aldol reaction.¹⁵

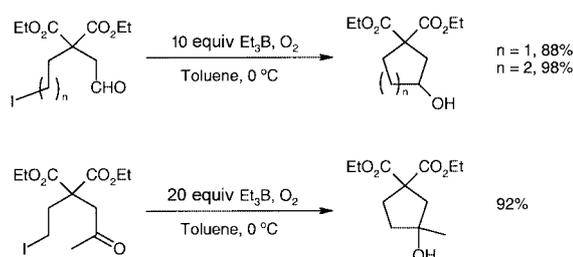
It has been noted, especially for radical reactions, that the quality of the triethylborane used is critical. In general, freshly opened bottles of commercial solutions or solutions freshly prepared from pure material give the best results.^{4,16}

Abstracts

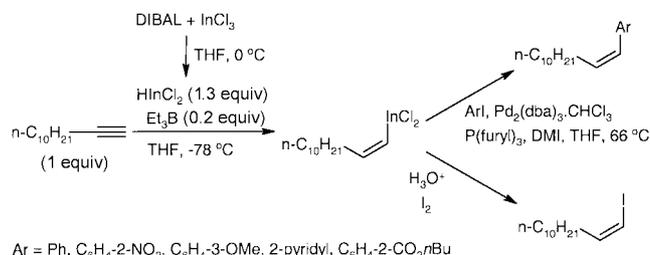
(A) Sibi and co-workers used triethylborane as the radical initiator in their enantioselective syntheses of butyrolactone natural products. Lewis-acid mediated radical addition to differentially protected fumarate **1** gave addition product **2** in 80% yield as a single diastereoisomer. This was further elaborated to afford the dibenzylbutyrolactone lignan (–)-arctigenin. Similar chemistry was used to synthesise the butyrolactone natural products (–)-enterolactone, (–)-isoarctigenin, (–)-nephrosteranic acid and (–)-roccellaric acid.²



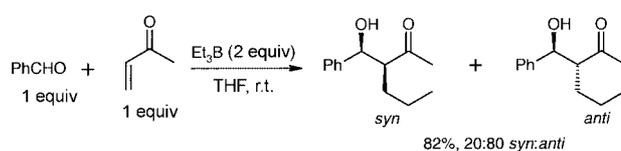
(B) Malacria and co-workers used triethylborane/O₂ as the radical initiator in their tin-free method for the intramolecular addition of alkyl radicals to aldehydes and ketones.⁵ Efficient cyclisation of ω-iodoaldehydes was accomplished with 10 equivalents of triethylborane. ω-Iodoaldehydes required 20 equivalents of triethylborane to ensure a good yield of the desired product. The use of triethylborane as a radical initiator reverses the selectivity observed in the cyclisation of enal precursors with AIBN/Bu₃SnH, with cyclisation onto the carbonyl carbon preferred with triethylborane. This is attributed to the Lewis acidity of the borane.



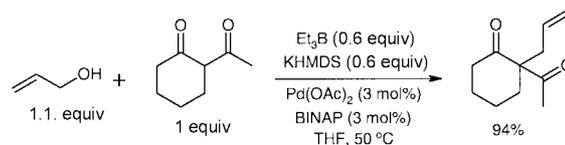
(C) Triethylborane has been used in the radical hydroindation of alkynes and alkenes.⁹ Alkenylindiums generated by this means can be employed in a one-pot cross-coupling with aryl halides or trapped with various electrophiles. The hydroindation of alkynes and subsequent palladium-catalysed cross-coupling proceeds with high (*Z*)-selectivity. The (*Z*)-alkenylindiums thus formed can also be trapped with various electrophiles, such as water and I₂, with retention of the alkenylindium stereochemistry. Hydrogallation proceeds with lower (*Z*)-selectivity.



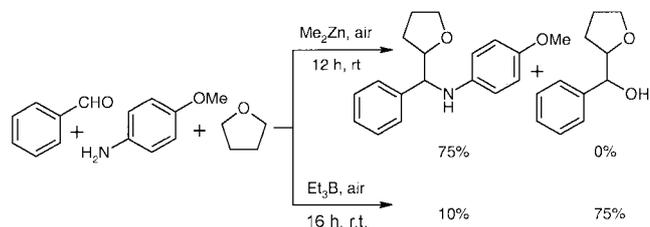
(D) Chandrasekhar and co-workers reported the first non-metal mediated tandem Michael-aldol reaction for the synthesis of α-alkyl-β-hydroxy ketone derivatives using triethylborane.¹⁵



(E) Tamaru and co-workers have used triethylborane as an efficient promoter of the palladium-catalysed allylation of active methylene compounds with unactivated allylic alcohols.¹⁶ The primary role of the borane is to activate the C–O bond of the allylic alcohol towards oxidative addition by the Pd⁰ species.



(F) Tomioka and co-workers have investigated the initiator-dependent chemoselective addition of THF radical to aldehydes and imines in a three component reaction. Triethylborane preferentially afforded the THF adduct of the aldehyde. The use of dimethylzinc as initiator preferentially gave the THF adduct of the corresponding imine. The reason for this chemoselectivity is not explained.¹⁰



References

- (1) Nozaki, K.; Oshima, K.; Utimoto, K. *J. Am. Chem. Soc.* **1987**, *109*, 2547.
- (2) Sibi, M. P.; Liu, P. R.; Ji, J. G.; Hajra, S.; Chen, J. X. *J. Org. Chem.* **2002**, *67*, 1738.
- (3) Ishibashi, H.; Inomata, M.; Ohba, M.; Ikeda, M. *Tetrahedron Lett.* **1999**, *40*, 1149.
- (4) Ollivier, C.; Renaud, P. *Chem. Rev.* **2001**, *101*, 3415.
- (5) Devin, P.; Fensterbank, L.; Malacria, M. *Tetrahedron Lett.* **1999**, *40*, 5511.
- (6) Baguley, P. A.; Walton, J. C. *Angew. Chem. Int. Ed.* **1998**, *37*, 3073.
- (7) Ollivier, C.; Bark, T.; Renaud, P. *Synthesis* **2000**, 1598.
- (8) Miyabe, H.; Nishimura, A.; Fujishima, Y.; Naito, T. *Tetrahedron* **2003**, *59*, 1901.
- (9) Takami, K.; Mikami, S.; Yorimitsu, H.; Shinokubo, H.; Oshima, K. *J. Org. Chem.* **2003**, *68*, 6627.
- (10) Yamada, K.; Yamamoto, Y.; Tomioka, K. *Org. Lett.* **2003**, *5*, 1797.
- (11) Yorimitsu, H.; Oshima, K. *Bull. Chem. Soc. Jpn.* **2002**, *75*, 853.
- (12) Yorimitsu, H.; Shinokubo, H.; Oshima, K. *Synlett* **2002**, 674.
- (13) Kimura, M.; Mukai, R.; Tanigawa, N.; Tanaka, S.; Tamaru, Y. *Tetrahedron* **2003**, *59*, 7767.
- (14) Kimura, M.; Futamata, M.; Shibata, K.; Tamaru, Y. *Chem. Commun.* **2003**, 234.
- (15) Chandrasekhar, S.; Narsihmulu, C.; Reddy, N. R.; Reddy, M. S. *Tetrahedron Lett.* **2003**, *44*, 2583.
- (16) Tamaru, Y.; Horino, Y.; Araki, M.; Tanaka, S.; Kimura, M. *Tetrahedron Lett.* **2000**, *41*, 5705.