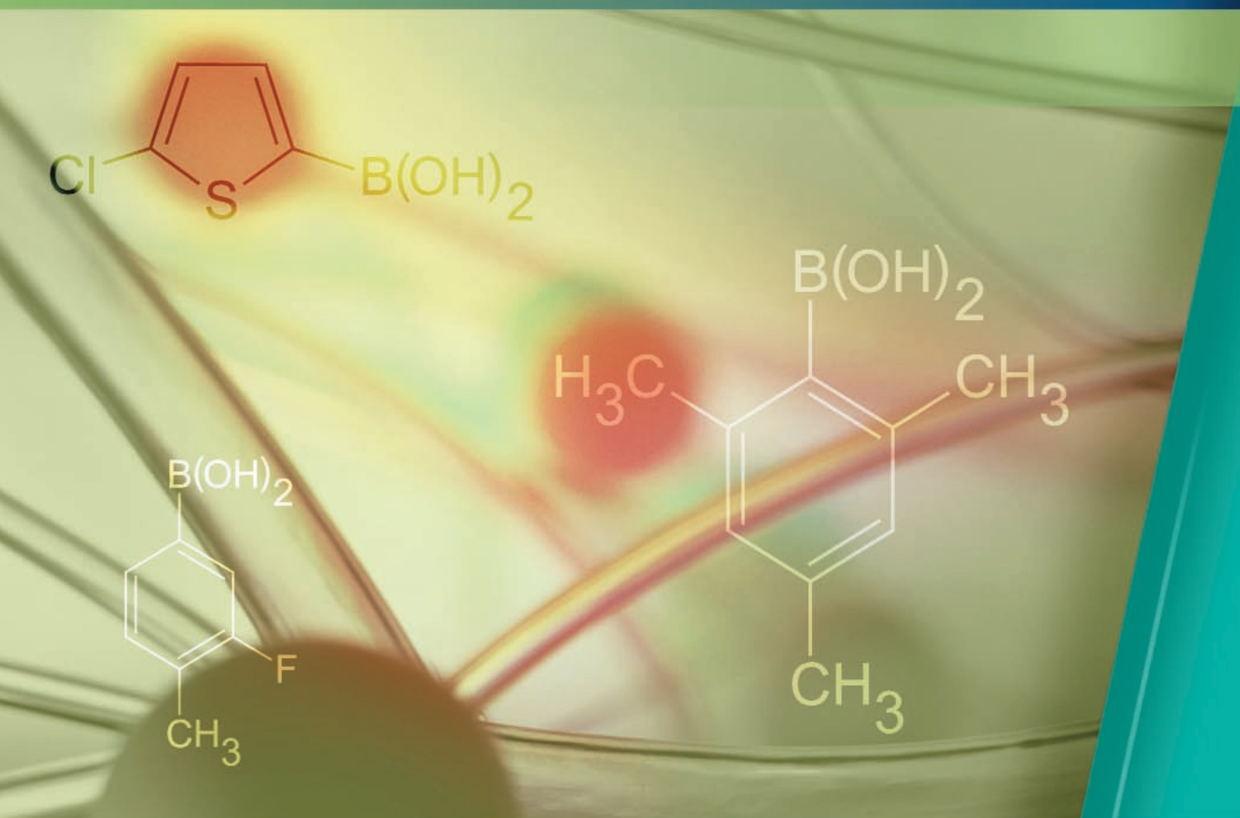
Boronic Acids

Properties and Applications



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Boronic Acids

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Within the field of organoboron chemistry, boronic acids have emerged in a leading role, with applications in synthesis, catalysis, analytical chemistry and in biological systems. The discovery of a wealth of new chemistry, in particular the Suzuki-Miyaura cross-coupling reaction, combined with their accessibility and ease of handling, have established boronic acids and boronates among the most frequently-encountered of intermediates. Nearly thirty years ago, Lancaster Synthesis, now incorporated in the Alfa Aesar group, pioneered the commercial production of a range of boronic acids for use in research and development. Since then, the astonishing growth of interest in the chemistry of these molecules has been paralleled by an enormous increase in the diversity of examples available from commercial sources, among which Alfa Aesar continues to hold a leading position. We can provide outstanding synthetic and analytical expertise in boronic acids, esters and related products. This publication outlines the chemical properties and highlights the main synthetic uses of these versatile molecules.

1. Introduction

Elemental boron is rather difficult to isolate in a pure state, in which it is usually obtained as an extremely hard, dark brown or black powder, mp 2075˚C. Its properties, such as electronegativity (Table 1), are those of a non-metal or metalloid, although organoboron compounds are often classed as organometallics, since they have certain similarities to compounds of some metallic elements.

Table 1: Electronegativities (Pauling) of representative elements[1]

H	2.20	Li	0.98
Be	1.57	Mg	1.31
B	2.04	Al	1.61
C	2.55	Si	1.90
N	3.04	P	2.19
O	3.44	S	2.58
F	3.98	Cl	3.16
Zn	1.65	Pd	2.20
Cu	1.90	Sn	1.96

Table 2 shows a representative selection of bond strengths involving boron, along with data for related elements for comparison.

Table 2: Typical covalent bond energies[1,2]

Bond	Bond energy $kJ\ mol^{-1}$	Bond energy $kcal\ mol^{-1}$
B–H	375	90
B–C	323	77
B–O	544	130
B–F	659	158
B–Cl	456	109
B–B	286	68
C–C	358	85
Li–C	126	30
Si–C	301	72
Sn–C	225	54

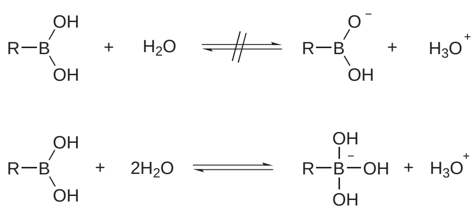
Organoboron compounds[3] tend to be air-sensitive, and in some cases pyrophoric materials. In work predating Mendeleev's periodic classification of the elements, Frankland[4] reported in 1859 the reaction of pyrophoric diethylzinc with triethyl borate to form a new pyrophoric product, triethylborane, readily oxidized by air to diethylborinic acid Et_2BOH. A second, slow oxidation step gave a more stable, crystalline product, identified as ethylboronic acid $EtB(OH)_2$. This sequence, the first known synthesis of a boronic acid, is inconvenient and of limited scope, but half a century elapsed before the publication of Khotonsky and Melamed's preparation of benzeneboronic acid from phenylmagnesium bromide and trimethyl borate,[5] which was to become the basis of the most generally useful route to boronic acids. The procedure was improved in the 1930s by Johnson,[6] and in the 1950s by Washburn.[7] Further details can be found in Section 4.

Although organoboron chemistry became a focus of attention in the second half of the 20th century, mainly due to the work of H. C. Brown, boronic acid chemistry continued to be a relative backwater over 100 years after Frankland's initial disclosure, but from the 1970s onwards, the level of interest has increased dramatically, as new applications have come to light. Whereas the chemistry of boronic acids could be covered by a 47-page review in 1964,[8] a recent comprehensive monograph on the subject runs to well over 500 pages.[9]

Most boronic acids are crystalline solids, easily handled in the presence of air and moisture. They are usually stable to long-term storage, but may undergo dehydration (see below) or, in some cases, are prone to air oxidation or gradual degradation. Where these may present a problem, either the corresponding boronate ester (Section 2) or trifluoroborate salt (Section 3) usually offers a satisfactory alternative which can undergo many of the reactions of the boronic acid itself. Such evidence as exists indicates that the boronic acid moiety is of relatively low intrinsic toxicity.[10] Recent applications in medicine support this view.[11] From an environmental perspective, boronic acids will degrade ultimately to the relatively benign boric acid, although the fate of the rest of the molecule will depend on the nature of any substituents.

Chemical character

Since the electron-deficient boron atom has a vacant p-orbital, boronic acids behave as mild Lewis acids, which can coordinate to Lewis bases. Hence, in water they tend to coordinate an OH group to form the tetrahedral anionic species, rather than acting as Brønsted acids by losing a proton (Scheme 1).[12] The measured acidity of arylboronic acids is comparable to phenols (benzeneboronic acid: pK_a 8.9 in water); alkylboronic acids are weaker. Electron-withdrawing substituents on the aryl group increase acidity, and electron-releasing groups decrease it.[13]



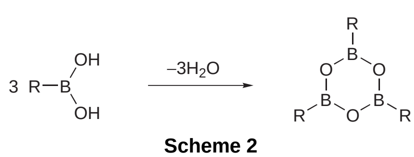
Scheme 1

In this review, the reactions of boronic acids are divided into two broad categories, according to whether they involve retention or cleavage of the boron-carbon bond, which are discussed in Sections 2 and 3 respectively. Section 4 outlines some of the preparative methods used for boronic acids and boronates.

2. Reactions in which the B–C bond is retained

Boroxine formation

Most boronic acids readily undergo dehydration (Scheme 2) to form the cyclic trimeric anhydride (boroxine; 1,3,5,2,4,6-trioxatriborinane). This often tends to occur spontaneously at room temperature, or in the course of drying, so that it may be difficult to obtain the acid free from the anhydride. Apart from difficulties in characterization (variable analyses and unreproducible melting points), this is rarely a serious problem, since in many applications, the acid and the anhydride are essentially indistinguishable.



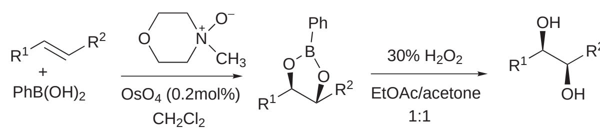
Scheme 2

However, if required, conversion of the boronic acid to a boronate ester with a suitable diol (see below) will prevent the dehydration reaction.

Boronate formation: protection of diols

Boronic acids react with alcohols, with loss of water, to form boronic esters (boronates). With simple alcohols, the products are very susceptible to hydrolysis, but with 1,2- and 1,3-diols, the resulting cyclic boronates (1,3,2-dioxaborolanes and 1,3,2-dioxaborinanes) are stable enough to be isolated.

The main early application was for protection and derivatization of 1,2- and 1,3-diols, particularly in carbohydrate chemistry.[14] These boronates have been widely used as volatile derivatives for GC and GC-MS purposes. They may be formed simply by stirring the boronic acid and diol together at ambient temperature, by warming, or, if necessary, with azeotropic removal of water. A detailed examination of boronic acid-diol complexation has been published.[15] Usually cleavage occurs readily under hydrolytic conditions, by exchange with a glycol,[16] or by treatment with hydrogen peroxide.[17] Hindered boronic esters, such as those of pinacol (2,3-dimethyl-2,3-butanediol), may be relatively stable to hydrolysis, and can often be purified by chromatography. A useful application of boronate protection is in the osmium(VIII) oxide catalyzed *cis*-dihydroxylation of alkenes under anhydrous conditions in the presence of a boronic acid (Scheme 3).[17b,18]



Scheme 3

Further information on the applications of boronic acids as derivatizing and protecting agents can be found in various reviews[19-21] and monographs.[22-24]

Other applications of diol boronates

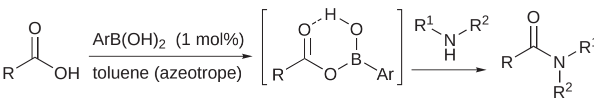
The formation of boronic esters with polymer-bound diols has been utilized as a linker system for solid phase synthesis, enabling modification of the polymer-bound boronic acid, followed by mild deprotection with methanol.[25]

Many other uses of boronates formed with carbohydrate molecules have been developed, including the selective transport of sugars in lipophilic environments,[26,27] and the design of artificial receptors, as discussed in several reviews.[28-32]

Boronic derivatives as activating and directing groups

The mild Lewis acidity of boronic acids, along with the ease of exchange around oxygen or nitrogen atoms attached to boron, has led to the application of the acids and their derivatives as catalysts or temporary scaffolds in a variety of regio-, stereo- and enantioselective syntheses.

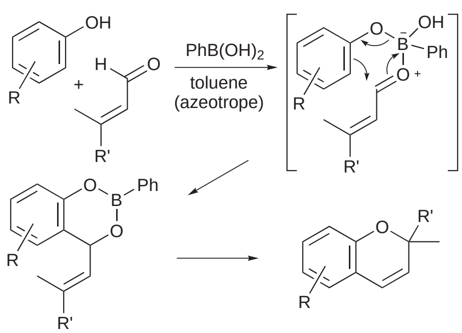
Arylboronic acids can behave as water-, acid-, and base-tolerant, thermally stable Lewis acids. Yamamoto has found that a boronic acid with electron withdrawing substituents, in particular 3,4,5-trifluorobenzeneboronic acid [Alfa Aesar product code **L18519**] can be an effective catalyst for amidation and esterification of carboxylic acids.[33] The reaction is thought to involve a 6-membered cyclic intermediate (Scheme 4).



Scheme 4

The amidation reaction has been extended to ureas.[34] 3,4,5-Trifluorobenzeneboronic acid also catalyzes the one-pot synthesis of acyl azides from carboxylic acids and sodium azide,[35] and the one-pot reduction of carboxylic acids to alcohols with sodium borohydride.[36] In some reactions, 3-nitrobenzeneboronic acid may be an effective catalyst, as in the transesterification of β-keto esters.[37] The use of arylboron compounds as acid catalysts was reviewed by Ishihara and Yamamoto.[38]

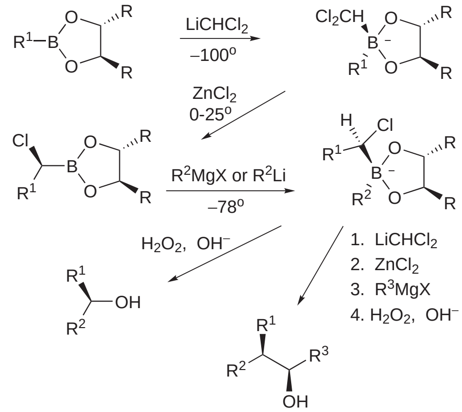
Benzeneboronic acid mediates the *ortho*-specific α-hydroxyalkylation of phenols by aldehydes.[39] The key intermediate is a cyclic boronate, formed via a [3,3] sigmatropic rearrangement. This process was utilized in the mild syntheses of benzo-fused heterocycles, including tetrahydrocannabinoids,[39b] and 2*H*-chromenes (Scheme 5).[40]



Scheme 5

Chiral boronates

Matteson has carried out extensive work on cyclic boronates,[41,42] formed from chiral diols, which undergo carbon insertion with $LiCHCl_2$ in the presence of zinc chloride in up to 99% diastereomeric excess (de). Treatment of the resulting α-chloro boronic esters with various nucleophiles leads to α-substituted boronic esters which can be oxidatively cleaved with hydrogen peroxide, or the sequence can be repeated to introduce a second chiral carbon atom, as illustrated in Scheme 6.

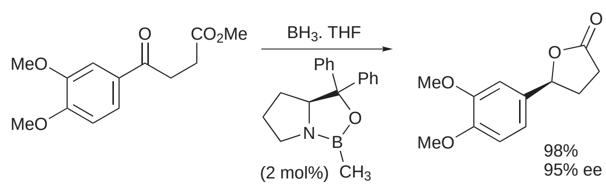


Scheme 6

Further aspects of this area of boronic ester chemistry have since been reviewed by Matteson.[43]

Oxazaborolidines

The reaction of a boronic acid with a chiral 2-amino alcohol gives an oxazaborolidine. These derivatives were introduced by Corey, Bakshi and Shibata[44] ("CBS" reagents) as excellent catalysts for enantioselective borane reduction of prochiral ketones (Scheme 7) with very high yield and enantiomeric excess (ee).

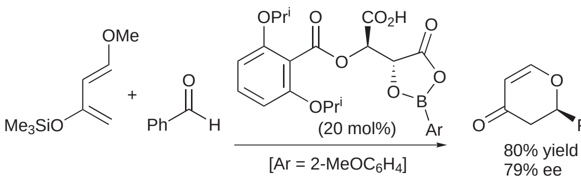


Scheme 7

The reagents derived from (R)- and (S)-α,α-diphenylprolinol [product codes **L09218** and **L09217**], usually with methylboronic acid: (R)- and (S)-2-methyl-CBS-oxazaborolidine **[L09230, L14582, L09219, L14583**], have received the most attention, although the use of other amino alcohols has been reported.[45,46] Reviews on the use of oxazaborolidines as enantioselective catalysts,[47,48] and the asymmetric reduction of ketones[49,50] are available.

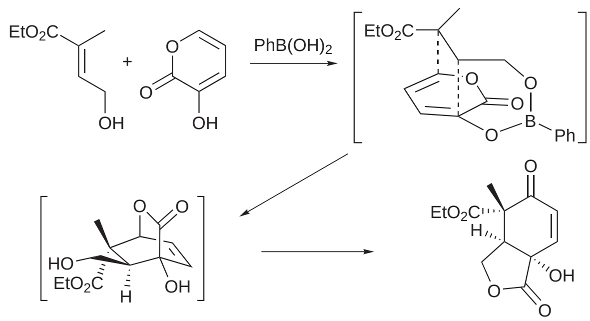
Diels-Alder reactions

Boronic acids can form stable chiral acyloxyborane (CAB) catalysts with tartaric acid derivatives. These compounds have been developed by Yamamoto as catalysts for asymmetric Diels-Alder[51] and hetero Diels-Alder[52] reactions, for example between aldehydes and Danishefsky's diene [1-methoxy-3-(trimethylsiloxy)-1,3-butadiene; [product codes **L06100** (94%) and **L14672** (98+%)], to give, enantioselectively, dihydro-4-pyrone derivatives (Scheme 8).[53]



Scheme 8

Benzeneboronic acid itself can be used as a template for Diels-Alder reactions by forming boronate linkages with a hydroxy diene and a hydroxy dieneophile,[54] an approach which was applied successfully by Nicolaou to synthesize the fully functionalized CD ring system of Taxol (Scheme 9).[55]



Scheme 9

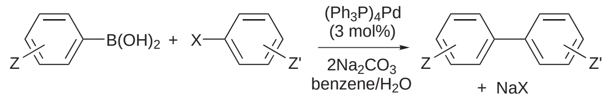
The use of boron acids as protective agents and catalysts in synthesis has been reviewed by Duggan and Tyndall.[21]

3. Reactions involving B–C bond cleavage

In the reactions described in the following sections, displacement of boron takes place with formation of a new carbon-carbon or carbon-heteroatom bond.

C–C bond-formation: the Suzuki-Miyaura cross-coupling reaction

In comparison with typical organometallic compounds of lithium, magnesium or the transition metals, the difference in electronegativity between boron and carbon is relatively small, and the boron-carbon bond strong (see Tables 1,2). Organoboron compounds, therefore, in the absence of a catalyst, normally exhibit very low reactivity towards electrophiles such as organic halides. In 1979, Suzuki and Miyaura reported the successful coupling of alkenylboranes and catecholyl boronates, in the presence of a Pd(0) catalyst and a base,[56] with alkenyl and alkynyl,[57] aryl[58] allyl and benzyl[59] halides. However, it was their discovery, published in 1981,[60] that stable, easily-handled arylboronic acids undergo palladium-catalyzed cross-coupling with aryl bromides and iodides in the presence of a base (Scheme 10), which stimulated the greatest interest in the application of this reaction. As a result, a plethora of applications and variants have subsequently been developed leading to the synthesis of unsymmetrical biaryls and many other types of coupled products.

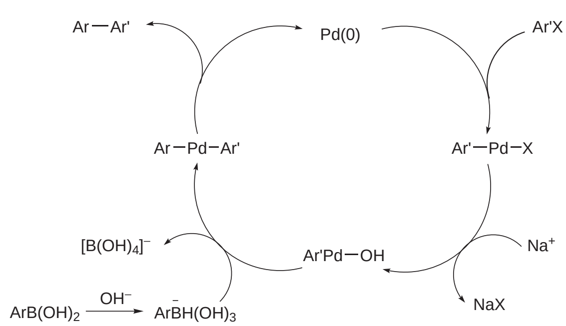


Scheme 10

Earlier methods employed for such syntheses generally involve the direct coupling of highly-reactive, usually moisture- and air-sensitive organometallic reagents (Grignard, organolithium, organozinc, etc.) with aryl halides, generally in the presence of a transition metal catalyst. Such reactions normally require strictly anhydrous conditions and an inert atmosphere, and are of limited scope, since the presence of many functional groups interferes. In contrast, Suzuki and Miyaura carried out the cross-coupling of boronic acids under aqueous conditions, and the reaction tolerates a wide variety of functional groups. The widely-used Stille cross-coupling reaction,[61] by comparison,[62] is also extremely versatile, and in some ways complementary to the boronic coupling, but involves toxic, environmentally hazardous organotin species.

Since its first disclosure, the cross-coupling reaction of boronic acids (usually known as the Suzuki or Suzuki-Miyaura reaction) has been developed in scope to become a cornerstone of modern synthetic organic chemistry. Under the standard coupling conditions, aryl bromides are most frequently used as the electrophilic species, but iodides may be preferred since they are more reactive. The successful coupling of the often more readily available and lower cost, but less reactive, aryl chlorides has been achieved under modified conditions, using a variety of palladium[64-69] or nickel[70,71] catalysts. Because of its versatility and the mild reaction conditions, the Suzuki coupling has been widely adopted for solid-phase synthesis on polymer supports.[72,73]

A proposed catalytic cycle for the reaction[74,75] is shown in Scheme 11. A detailed mechanistic study has also been published.[76]



Scheme 11

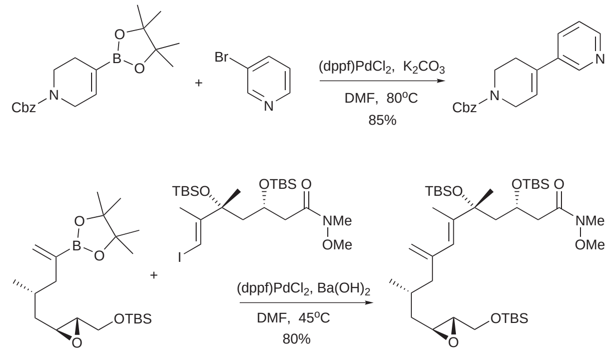
Suzuki and Miyaura's initial publication was followed by a series of papers by Gronowitz *et al*,[77] who showed that the deboronylation found as a side reaction, particularly with electron-rich boronic acids, could be minimized by using dimethoxyethane (DME) as solvent in conjunction with aqueous Na_2CO_3. This system was found to be applicable to a variety of aryl and heteroaryl substrates, and has been widely adopted by other workers. Alternative illustrative experimental procedures are described in *Organic Syntheses*.[78] Useful reviews of the Suzuki-Miyaura and related reactions have been published by Suzuki and Miyaura,[79,80] by Martin and Yang,[75] with particular emphasis on heteroaryl systems, and by Stanforth[81] on biaryl synthesis via cross-coupling reactions. The more recent literature on the Suzuki-Miyaura cross-coupling has been reviewed by Kotha *et al*.[82] A review of palladium-catalyzed coupling reactions of aryl chlorides, majoring on recent improvements, is also available,[83] as is a general review of aryl-aryl bond formation.[84]

Related coupling reactions

In early extensions of the biaryl coupling reaction, aryl- and heterorarylboronic acids were coupled with a variety of heterocyclic halides, including thiophenes,[85] furans, thiazoles,[86] isoxazoles,[87] pyridines,[64,88-90] quinolines,[88] pyrimidines,[86,89] and pyrazines.[89,90] Many further examples have subsequently been published.

Aryl[91,92] or vinyl[93] triflates also undergo boronic acid coupling, which usefully extends the scope of the reaction to phenols or enols. The relative reactivity of leaving groups is normally in the order $I^- > OTf^- > Br^- >> Cl^-$. Cross-coupling of boronate derivatives with aryl mesylates,[94,95] and tosylates,[96] catalyzed by nickel complexes, has also been described, as has palladium-catalyzed coupling with sulfonium salts.[97] Coupling of arylboronic acids with heteroaryl thioethers has been brought about with a palladium catalyst, mediated by a Cu(I) carboxylate,[98] while nickel-catalyzed coupling with aryl quaternary ammonium salts has also been reported.[99] Other substrates (Pd-catalyzed) for arylboronic acid cross-coupling include: benzyl bromides,[100] α-bromo esters,[101] vinyl halides,[102-104] allylic bromides[105] or acetates,[106] allenic alcohols,[107] propargylic alcohols,[108] and allylic alcohols (Pd-catalyzed[109] or Rh-catalyzed[110]).

As already stated, Suzuki and Miyaura's earliest papers on the cross-coupling reaction related to alkenylboranes and boronic esters of catechol,[57,58] and, although the use of free boronic acids now predominates, aryl and enol boronates, particularly with pinacol (2,3-dimethyl-2,3-butanediol), still find use in the reaction, particularly in examples where they are more accessible via coupling or hydroboration methods (see Section 4), or more stable, than the corresponding free boronic acids. This is frequently an advantage in complex, multi-step syntheses, where the boronate substituent can be introduced under mild conditions, and may then be utilized to form a C–C bond with a preformed electrophilic fragment. Scheme 12 illustrates examples of boronate coupling.[111,112]



Scheme 12

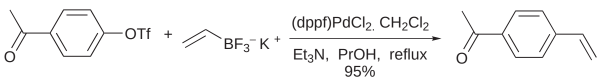
There are relatively few accounts of boronic acids coupling with unactivated alkyl halides, although these have begun to appear, mainly due to the work of Fu, who has described conditions for Pd-catalyzed coupling of aryl-, alkenyl- or alkylboronic acids with primary alkyl halides, in the presence of hindered phosphines, such as tricyclohexylphosphine or particularly $P(t\text{-}Bu)_2Me$,[113] and also of the Ni-catalyzed coupling of aryl- and alkenylboronic acids with secondary alkyl bromides and iodides, in the presence of a phenathroline ligand.[114]

Improved syntheses and availability from commercial sources, including Alfa Aesar, of boronic acids derived from electron-deficient hetereroaryl systems (e.g. pyridines) make their use more attractive. There are several reviews on the chemistry of these molecules.[115-118]

Coupling reactions of organotrifluoroborate salts

Darses and Genêt showed that the cross-coupling of arylboronic acids with arenediazonium tetrafluoroborates, catalyzed by palladium acetate in dioxane or methanol, needed neither added base nor phosphine ligand.[119] They applied similar conditions to the coupling of diazonium tetrafluoroborates with potassium aryl trifluoroborates,[120] which are air-stable crystalline solids readily prepared from arylboronic acids and KHF_2, and potassium vinyl trifluoroborates,[121] which are also readily isolable crystalline solids, more stable than the corresponding vinylboronic acids. The cross-coupling of potassium aryl and heteroaryl trifluoroborates with aryl and heteroaryl halides was subsequently described by Molander.[122] For aryl and electron-rich heteroaryl (e.g. thiophene) trifluoroborates, these reactions proceed in the presence of $Pd(OAc)_2$ under ligandless conditions. However he found that for electron-deficient heteroaryl (e.g. pyridine) trifluoroborates, the use of a liganded catalyst, [1,1'-bis(diphenylphosphino)-ferrocene]palladium(II) chloride, was necessary to give satisfactory yields.[122b] Conditions for coupling potassium aryl and heteroaryl trifluoroborates with aryl and heteroaryl triflates have also been reported.[123] In general, trifluoroborate salts are more nucleophilic than the equivalent boronic acids.[120,124] Furthermore, they are often more crystalline and more stable to long-term storage.

Molander has also demonstrated the coupling of potassium alkenyl trifluoroborates with aryl halides and triflates (Scheme 13), greatly extending the usefulness of these intermediates.[125] In the case of potassium vinyltrifluoroborate [**L17970**], high yields of Suzuki coupling products are obtained free from the products of Heck coupling observed with vinylboronic esters (see Section 4).[126]

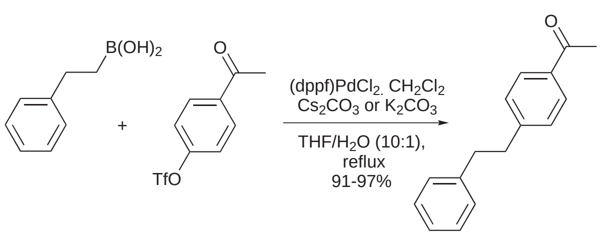


Scheme 13

Potassium alkenyl trifluoroborates also couple with alkenyl bromides, affording, 1,3-dienes with retention of double-bond geometry.[127]

Alkylboron couplings

Suzuki-Miyaura coupling of alkylboronic acids was described as difficult to accomplish and limited in scope.[128] However, Molander subsequently reported conditions under which primary alkylboronic acids can be coupled efficiently with aryl halides and triflates (Scheme 14).[129]

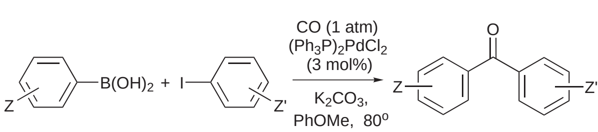


Scheme 14

This has been extended to the coupling of potassium alkyl trifluoroborates with aryl halides and triflates, catalyzed by $(dppf)PdCl_2$.[130]

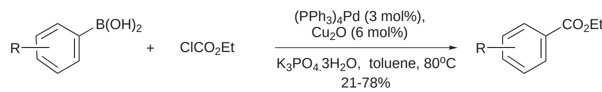
Formation of carbonyl compounds

Suzuki and Miyaura reported a variation of the biaryl coupling reaction, shown in Scheme 15, in which carbonylative cross-coupling of arylboronic acids with aryl iodides occurs in the presence of carbon monoxide at atmospheric pressure, to give unsymmetrical substituted benzophenones.[131]



Scheme 15

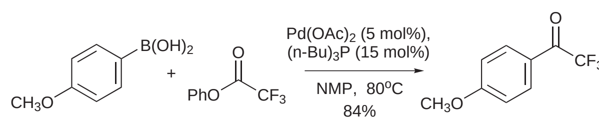
In contrast, Uemura found that, in the absence of an aryl halide, carbonylation of an aryl- or alkenylboronic acid, with a Pd(0) catalyst in THF, leads to the corresponding symmetrical ketone. In methanol without added base, a mixture of the ketone and the methyl aryl or alkenyl carboxylic ester is formed, whereas in the presence of sodium acetate, the methyl ester is the major product.[132] Unsymmetrical ketones were later prepared by reaction of arylboronic acids with acyl chlorides, catalyzed either by $(Ph_3P)_4Pd$,[133] $(Ph_3P)_2PdCl_2$,[134] or $Pd(OAc)_2$ with no added ligand,[135] and also with anhydrides, catalyzed by rhodium complexes.[136] A route to esters and amides is available via the coupling of arylboronic acids with chloroformates (Scheme 16).[137]



Scheme 16

Similarly, tertiary amides have been prepared by reaction of arylboronic acids[137] or arylboronates[138] with N,N-dialkylcarbamoyl chlorides.

Coupling reactions of arylboronic acids with S-phenyl trifluorothioacetate, with $Pd_2(dba)_3$ and a Cu(I) co-catalyst,[139] or with phenyl trifluoroacetate, or the phenyl ester of another perfluoroalkanoic acid, catalyzed by $Pd(OAc)_2$[140] (Scheme 17), have been used to prepare the corresponding aryl perfluoroalkyl ketones.

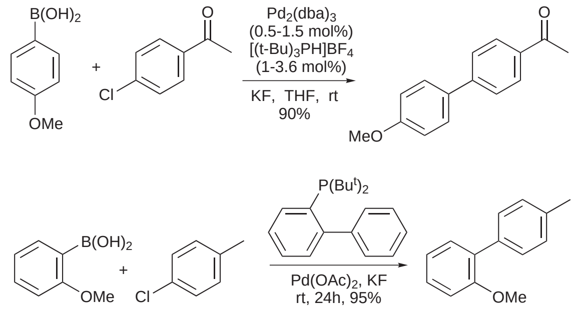


Scheme 17

Catalyst systems

In the original biaryl coupling work, Suzuki and Miyaura[60] employed the readily-available complex tetrakis(triphenyl-phosphine)palladium(0), which continues to be the preferred catalyst in most routine syntheses. An extremely wide variety of alternative catalyst and ligand systems have been reported, with advantages in cost, efficiency or selectivity for particular applications. Examples include: $(Ph_3P)_2PdCl_2$,[87,131] $(dppb)PdCl_2$,[89,141] $Pd(dba)_n$[115,142] $Pd(OAc)_2$,[119,143] $Pd(OAc)_2/(o\text{-tol})_3P$,[90,144] $Pd(OAc)_2$/dppf,[90] $PdCl_2$/pyridine,[145] $(dppf)PdCl_2$,[101,104,111,112,129,130,146] $(PhCN)_2PdCl_2/Ph_3As$,[103] $(CH_3CN)_2PdCl_2$,[131] palladium on carbon,[65,88,147,149] palladium on a polymer support,[64,150] $(Ph_3P)_2NiCl_2$,[70,95] $NiCl_2.6H_2O$,[71] and the palladacycle complex *trans*-di-μ-acetatobis[2-(di-*o*-tolylphosphino)-benzyl]dipalladium(II).[151] Low-cost trialkyl phosphites have also been successfully used as ligands in palladium-[152,153] and nickel-[152] catalyzed couplings. As an alternative to phosphorus(III) derivatives, inexpensive 1,4-diazabicyclo[2.2.2]octane (Dabco), in the presence of $Pd(OAc)_2$ has been found to be an effective ligand.[154,155]

$Pd_2(dba)_3/(t\text{-Bu})_3P$,[120] and the air-stable equivalent $Pd_2(dba)_3/[(t\text{-Bu})_3PH]BF_4$,[121] developed by Fu's group, as well as Buchwald's biphenylphosphine systems, e.g. $Pd(OAc)_2$/2-(di-*tert*-butylphosphino)biphenyl.[69] are good for coupling difficult substrates, including aryl chlorides, under mild conditions (Scheme 18).



Scheme 18

The use of tetrakis(triphenylphosphine)platinum(0) instead of the palladium(0) complex permits selective coupling with an aryl iodide in the presence of an aryl bromide.[156]

A comprehensive range of coupling catalyst systems, including most of those mentioned above and some more specialized systems, is available from Johnson Matthey Catalysts. These products are offered in research quantities through Alfa Aesar, and are listed in the Product section of this publication. Further technical information on the uses of these catalysts is available on request.

Bases

In contrast to the coupling reactions of organotin or organozinc reagents, Suzuki and Miyaura found that the arylboronic acid coupling requires 2 equivalents of a base, originally aqueous sodium carbonate.[56,60] They also reported that the stronger bases ethoxide or hydroxide gave poorer yields than carbonate, and that sodium acetate was ineffective, although its use under modified conditions has since been reported.[157] Many alternative bases have been introduced for these reactions, some of which offer advantages for particular substrates; examples include: $NaHCO_3$,[87,158] K_2CO_3,[92,111] Cs_2CO_3,[63b] K_3PO_4,[94] Et_3N/DMF,[90] Ag_2O,[103] $Ba(OH)_2$,[112,159] good for sterically-hindered biaryls, and CsF,[160] compatible with readily-hydrolyzed functionality, such as esters.

Other reaction conditions

Many Suzuki-Miyaura biaryl coupling reactions described in the literature use an aqueous mixed solvent with a water-miscible component such as DME or 1,4-dioxane. Examples have appeared of the use of poly(ethylene glycol)[155,161,162] or poly(ethylene oxide)[163] as co-solvent, potentially replacing volatile organic solvents, and facilitating recycling of the catalyst system.

The coupling reaction of arylboronic acids with aryl bromides is dramatically accelerated by using the ionic liquid, 1-*n*-butyl-3-methylimidazolium tetrafluoroborate [bmim][BF_4] as the reaction medium; improved yields with reduced catalyst loading of $(Ph_3P)_4Pd$ are claimed.[164] 4-Iodophenol immobilized on Wang resin undergoes accelerated coupling with the same catalyst in [bmim][BF_4].[73] The application of ultrasound, also in [bmim][BF_4], with ligand-free $Pd(OAc)_2$ as catalyst and NaOAc as base, has been found to promote rapid coupling at ambient temperature under extremely mild conditions.[157] Water dramatically accelerates the $Pd(OAc)_2$-catalyzed coupling of aryl halides in [bmim][BF_4] and [bmim][PF_6], enabling multiple recycling of the catalyst system.[165] A short review article on palladium-catalyzed C-C coupling reactions in ionic liquids is available.[166]

Arylboronic acids also undergo *rhodium*-catalyzed, copper-mediated coupling with allylic alcohols in [bmim][PF_6].[116] At elevated temperatures, the simple phase-transfer catalyst tetra-n-butylammonium bromide (TBAB) behaves as an ionic liquid; mixtures with water have been utilized by Bedford for the ligand-free $Pd(OAc)_2$-catalyzed cross-coupling of aryl chlorides.[66]

Leadbeater studied the accelerating effect of microwaves on ligand-free $Pd(OAc)_2$-catalyzed Suzuki-type couplings in water, with or without TBAB.[167] He also demonstrated Suzuki coupling of aryl chlorides using palladium on carbon catalyst in water with microwave heating and simultaneous cooling.[168] Yu has reported improved yields with aryl chlorides using a Pd-phosphine complex in aqueous media.[169] Leadbeater's claim[170] to have achieved microwave-promoted, transition metal-free coupling was later retracted, with the detection of traces of palladium in the sodium carbonate base.[171] Microwaves also enable cross-coupling of organotrifluoroborates with ultra-low (ppm) catalyst loadings.[172] "Environmentally friendly" Suzuki reactions have been reviewed.[173]

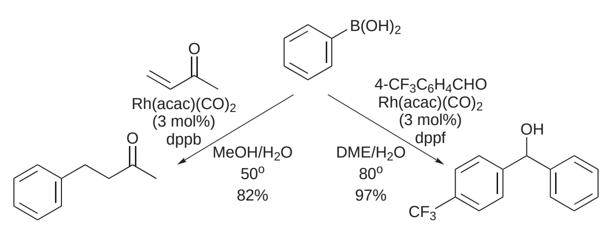
1,2- and 1,4-additions to carbonyl compounds

Palladium-catalyzed reactions

Uemura reported palladium-catalyzed 1,4-addition of arylboronic acids to enones,[174] but yields were generally poor. Ohta has since found that 1,2-addition of arylboronic acids to aldehydes, catalyzed by Pd(0), can be effected, but only in the presence of chloroform.[175a] Organoboronic acids also undergo 1,4-addition to α,β-unsaturated ketones with a Pd phosphine complex and chloroform.[175b]

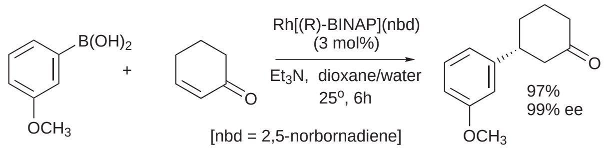
Rhodium-catalyzed reactions

Miyaura and Hayashi described the conjugate addition of arylboronic acids to enones, catalyzed by a rhodium(I) complex and a chelating phosphine, to give good yields of saturated ketones.[176] Under similar conditions, both aryl- and alkenylboronic acids can add to aldehydes to give secondary alcohols in high yield (Scheme 19).[177]



Scheme 19

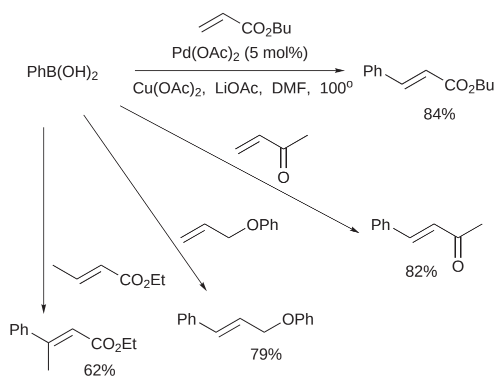
An extension of these reactions to the addition of potassium alkenyl- and aryltrifluoroborates to aldehydes and enones has been described.[178,179] Miyaura and Hayashi utilized the Rh(I)-catalyzed 1,4-addition reaction of boronic acids to α,β-unsaturated ketones,[180] esters[181] or amides,[182] in the presence of a chiral BINAP ligand, in enantioselective syntheses of the corresponding saturated ketones and esters. This area was reviewed by Hayashi.[183] Further investigations of the 1,4-addition reactions have led to improved results under milder conditions (Scheme 20).[184] New results in this field continue to appear on a regular basis.[185]



Scheme 20

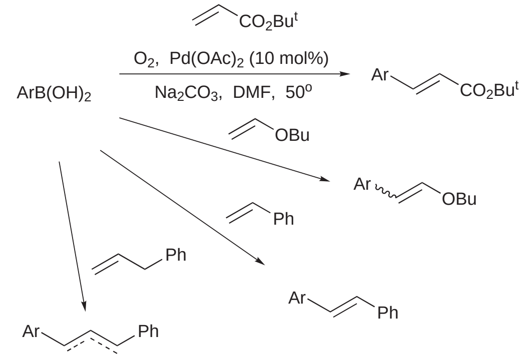
Mizoroki-Heck and other transition metal-catalyzed reactions with alkenes and alkynes

Uemura reported the $Pd(OAc)_2$-catalyzed cross-coupling of arylboronic and alkenylboronic acids with alkenes in acetic acid to give aryl-substituted alkenes and conjugated dienes respectively, by oxidative addition of the B-C bond to an *in situ* formed Pd(0) species.[186] Subsequently, Mori described a Pd(II)-catalyzed pathway, employing catalytic $Pd(OAc)_2$ with $Cu(OAc)_2$ as stoichiometric co-oxidant.[187] Treatment of a variety of alkenes with arylboronic acids thus affords β-arylated products in good yield (Scheme 21). The reaction conditions were also adapted to permit the coupling of sodium tetraphenylborate or alkenylboronates.



Scheme 21

Jung has demonstrated the palladium-catalyzed oxygen-promoted coupling of a number of aryl and heteroaryl boronic acids and boronates with a variety of olefins in good yields under mild conditions (Scheme 22).[186]

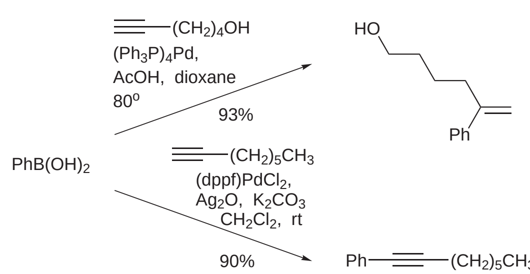


Scheme 22

In contrast, with electron-rich olefins (vinyl ethers and N-vinylamides), the use of a phenanthroline ligand, promotes Pd-catalyzed Heck arylation at the internal (heteroatom-substituted) position.[189] Arylboronic acids also undergo aerobic Pd-catalyzed Heck-type coupling with phenyl vinyl sulfones[190] and vinylphosphonates.[191]

Conditions for Heck-type reactions of arylboronic acids with acrylate esters to give cinnamic esters have been described by Brown, with a ruthenium catalyst in the presence of a Cu(II) oxidant,[192] and by Zou, with a rhodium catalyst.[193]

Lautens has investigated the rhodium catalyzed coupling of boronic acids with alkenes and alkynes in aqueous systems. In the presence of $[Rh(COD)Cl]_2$ and a water-soluble phosphine ligand, arylboronic acids undergo a Heck-type reaction with styrenes to give *trans*-stilbenes, whereas, with vinyl-substituted pyridines, quinolines or pyrazine, hydroarylation of the olefinic bond gives the saturated 2-arylethyl heterocycle.[194] Alkynyl heteroaromatic compounds under analogous conditions also undergo hydroarylation to 2-arylvinyl derivatives.[195] Stereoselective rhodium-catalyzed hydroarylation of internal alkynes had previously been demonstrated by Hayashi.[196] Terminal alkynes with a palladium catalyst can undergo either hydroarylation by arylboronic acids, reported by Oh,[197] or Heck-type coupling under oxidative conditions, by Zou (see Scheme 23).[198] The regioselectivity of palladium-catalyzed hydroarylation of unsymmetrical internal alkynes has been studied by Oh.[199]

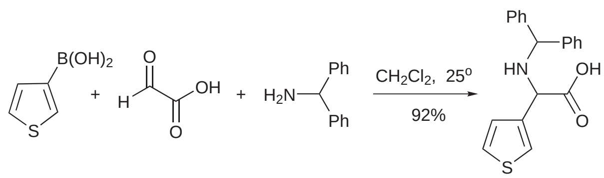


Scheme 23

Internal alkynes undergo addition with arylboronic acids, affording tetrasubstituted olefins.[200]

The Boron-Mannich (Petasis) reaction

Petasis initially described the Mannich-type reaction of alkenylboronic acids with paraformaldehyde and secondary amines,[201] affording allylamines in good yield with retention of double-bond geometry. Subsequently, he developed the three-component Mannich reaction of an alkenylboronic acid with glyoxylic acid and an amine to give β,γ-unsaturated α-amino acid derivatives,[202] which was extended to the synthesis α-aryl and α-heteroaryl glycines from the corresponding boronic acids,[203] as shown in Scheme 24.



Scheme 24

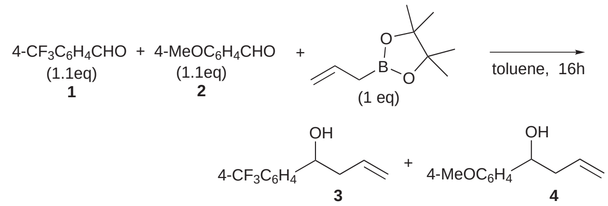
Harwood and co-workers demonstrated the use of a chiral secondary amine as a template in a diastereo-controlled Mannich reaction with furan-2-boronic acid [**L15297**], to give substituted furfurylamines with high de.[204] The Petasis reaction has been investigated with one of the three components anchored to a polymer support, and found to give satisfactory results in most cases.[205] The reaction has also been successfully extended to pinacolyl boronic esters,[206] with chiral induction achievable via a homochiral boronic ester.[207]

Petasis has reported an analogous stereocontrolled three-component condensation, involving a boronic acid, an amine and an α-hydroxy aldehyde, to yield the *anti*-β-amino alcohol.[208] This route has been adapted to give the product enantioselectively with high ee.[209]

The Petasis reaction has been extended to the more reactive potassium organotrifluoroborates (aryl, vinyl and allyl), which undergo a Mannich-type condensation with an aldehyde and an amine, in the presence of a Lewis acid.[210] Alkenyl, aryl and heteroaryl pinacol boronates react slowly or not at all in the Petasis reaction in aprotic solvents. In alcohols such as methanol or hexafluoroisopropanol, the reaction proceeds well to give amino acid derivatives, mostly in high yield.[211]

Allylation reactions

Allylboronic esters can add stereoselectively to aldehydes, in the absence of a catalyst, to give homoallylic alcohols.[41c] Ishiyama and Miyaura have shown that the reaction of pinacolyl allylboronates is dramatically accelerated, and the chemoselectivity increased, by a catalytic amount of a Lewis acid (Scheme 25).[212] The potential for modest enantioselectivity was demonstrated in the presence of a BINOL co-catalyst.



Catalyst	Temp	Yield%	3:4
none	r.t.	89	81:19
none	−78°	0	
$AlCl_3$ (10 mol%)	−78°	57	99:1
$Sc(OTf)_3$ (10 mol%)	−78°	72	99:1

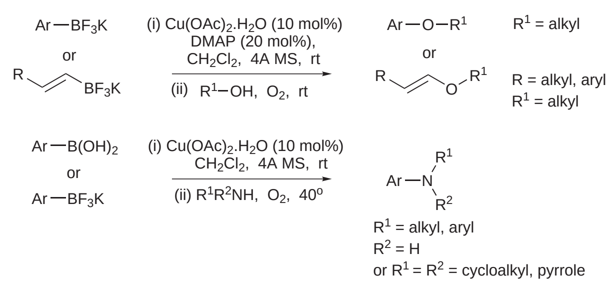
Scheme 25

C–O, C–N and C–S bond forming reactions

Oxidative cleavage of organoboron compounds to give alcohols or phenols is well known. In the case of boronic acids and esters, conditions utilizing hydrogen peroxide[17,213] or Oxone® [214] have been described.

More useful synthetic reactions are the C–O and C–N coupling of arylboronic acids with phenols,[215,216] N-hydroxyphthalimide,[217] amines,[216,218] amides and imides,[216,219] ureas, sulfonamides and carbamates,[215] and N-heteroaromatics,[220] mediated by copper(II) acetate, to give the corresponding diaryl ethers, arylamines or N-aryl heterocycles. The C–N coupling reaction has been applied to solid-phase synthesis of N-heterocycles.[221] The formation of unsymmetrical thioethers from arylboronic acids and thiols, mediated by $Cu(OAc)_2$ has been reported.[222] Alkyl and aryl sulfinic acid salts also react with arylboronic acids, in the presence of $Cu(OAc)_2$, to give good yields of aryl sulfones.[223]

As originally described, these reactions required stoichiometric amounts of Cu(II). Buchwald reported a catalytic procedure for amination utilizing molecular oxygen as reoxidant for copper,[224] and Batey has since developed improved oxygen-mediated catalytic procedures for the formation of ethers from trifluoroborate salts (or, in reduced yield, boronic acids) and aliphatic alcohols,[225] and also for amination of both boronic acids and trifluoroborates (Scheme 26).[226]



Scheme 26

Arylboronic acids undergo reductive amination with arylnitroso compounds, mediated by Cu(I), providing a route to unsymmetrical diarylamines.[227]

Unsymmetrical diaryl or aryl heteroaryl sulfones have been prepared via a ligand-free, palladium chloride-catalyzed coupling of arylboronic acids with arylsulfonyl chlorides.[228]

Miscellaneous displacement reactions of boronic acids

Many other examples can be found of boronic acid chemistry involving displacement of boron:

Reaction of arylboronic acids with copper(II) chloride or bromide to give the corresponding aryl halide with loss of boron has long been known.[229] More recently, *ipso*-bromination or -iodination of arylboronic acids with NBS or NIS in acetonitrile has described.[230] The reaction has been further developed utilizing 1,3-dibromo-5,5-dimethylhydantoin and the dichloro analogue, providing convenient access to "abnormally" substituted bromo and chloro aromatics.[231] A catalytic amount of sodium methoxide was found to minimize side reactions, affording high yields of the required products. Potassium aryltrifluoroborates salts undergo *ipso*-iodinations using a combination of sodium iodide and Chloramine-T.[232] Arylboronic acids have been converted, via the N-methyldiethanolamine cyclic esters, to aryl fluorides using cesium fluoroxysulfate.[233] Widdowson and co-workers[234] have demonstrated the facile conversion of arylboronic acids to diaryliodonium triflates in the presence of $PhI(OAc)_2$/TfOH. Diaryl and heteroaryl (phenyl)iodonium tosylates can also be readily prepared from the corresponding boronic acid and Koser's reagent [PhI(OH)OTs]. This approach is preferable to the previous route via toxic stannanes. The displacement reaction of iodonium salts with fluoride ion provides a mild synthesis of aryl fluorides, including ^{18}F labelled derivatives, which can be employed in positron emission tomography.

Vinylboronic acids can be converted to vinyl halides, with retention of double-bond configuration, using NCS, NBS or NIS.[235] Vinyl and alkynyl trifluoroborates can be iodinated with sodium iodide/ Chloramine-T.[236] Fluorination of vinylboronic acids occurs with 1-chloromethyl-4-fluoro-1,4-diazoniabicyclo[2.2.2]octane bis(tetrafluoroborate) [Selectfluor®; **L17003**], but better results have been obtained starting from the corresponding potassium alkenyl trifluoroborates.[237]

Arylboronic acids undergo *ipso*-nitration with ammonium nitrate/ trifluoroacetic anhydride[238] (Crivello's reagent: *in situ* trifluoroacetyl nitrate), or, more selectively, with a nitrate salt and TMS chloride,[239] to give the boron-free aryl nitro compound, in contrast to conventional nitration which tends to give mainly the *m*-nitrobenzeneboronic acid.

With lead(IV) acetate, catalyzed by mercury(II) acetate, arylboronic acids are transmetallated to the aryllead triacetates, used *in situ* for electrophilic arylation, for example of active methylene compounds,[240] or with sodium azide in DMSO for the preparation of aryl azides, providing a useful two-step route for the preparation of these from aryl halides.[241]

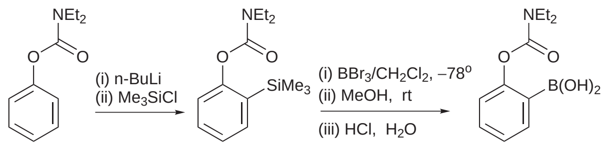
Transmetallation of an arylboronic acid to an arylzinc species *in situ* has been achieved with diethyzinc.[242]

4. Preparative routes to boronic acids and esters

Boronylation of organometallics

Boronic acids are most often prepared from the corresponding organomagnesium or organolithium reagent and a trialkyl borate, followed by acidic hydrolysis of the resulting dialkyl boronate. The original conditions of Kotinsky and Melamed,[5] addition of trimethyl borate to an ether solution of phenylmagnesium bromide, were repeated by Gilman,[243] who claimed yields of benzeneboronic acid as high as 86%. However, most other workers were unable to reproduce this, and often obtained only very low yields, mainly due to the formation of large amounts of diphenylborinic acid. Johnson subsequently used a reverse-addition technique, adding the ethereal phenyl Grignard to trimethyl borate at –12˚C (ca 30% yield),[6a] or to tributyl borate at –70 to –75˚C, (50-60% yield).[6b] Washburn later undertook a more detailed study of the synthesis of benzeneboronic acid from phenylmagnesium bromide and trimethyl borate,[7] confirming that the yield of boronic acid is much improved by carrying out the boronylation of the Grignard at low temperatures (generally below –50^{o}C). As the reaction temperature approaches ambient, increasing amounts of the ester of diphenylborinic acid are formed by further attack of the Grignard on the intermediate dimethyl benzeneboronate. He also demonstrated that simultaneous addition of the borate and Grignard to a vessel containing ether stirred at low temperature tended to minimize formation of diphenylborinic acid. In a second key paper[244] Washburn discussed further experimental and mechanistic aspects of the reaction of phenyl- and substituted phenylmagnesium halides with trialkyl borates. His optimal procedure for benzeneboronic acid is detailed in *Organic Syntheses.*[245] The results of other workers indicate that the use of triisopropyl borate[246] or isopropyl pinacol borate (2-isopropoxy-4,4,5,5-tetramethyl-1,3,2-dioxaborolane)[247] [**L17278**] instead of trimethyl borate may have advantages in particular cases.

Snieckus has developed directed metallation[248] routes to boronic acids. His initial publication[249] described *ortho*-lithiation of N,N-dialkyl benzamides, followed by boronylation with trimethyl borate. In a subsequent paper,[250] better results for a range of substrates were claimed by an *ortho*-lithiation-silylation-*ipso*-boro-desilylation[251] sequence with boron tribromide (Scheme 27).

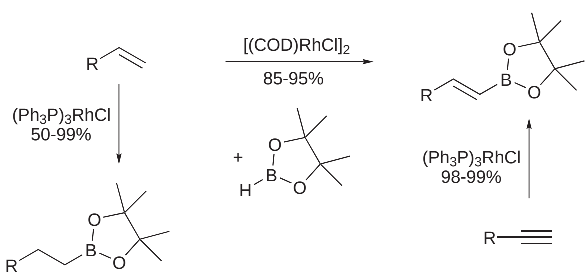


Scheme 27

Other workers[252] have utilized *ipso*-borodesilylation with either BBr_3 or BCl_3 in the formation of boronic acids and esters. Neopentyl esters have been *ortho*-lithiated with LDA and reacted with triisopropyl borate *in situ* to give good yields of arylboronic acids, isolated via the diethanolamine esters.[253]

Hydroboration methods

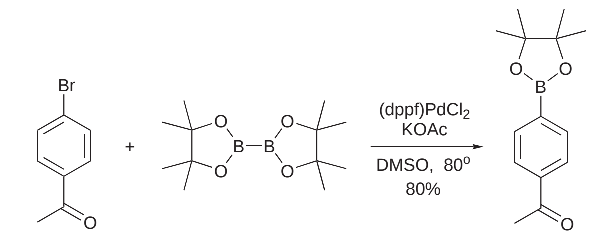
Hydroboration of alkenes with catecholborane to give alkylboronic esters[254] usually requires forcing conditions. Improved results can be obtained by catalysis with $LiBH_4$,[255] or with Rh(I)[256,257] or Ir(I)[257] complexes. Hydroboration of alkynes with catecholborane occurs somewhat more readily, affording alkenylboronic esters, often regio- and stereoselectively.[254] Nevertheless, catalysis with, for example Rh(I),[256] Ni(II)[258] or Pd(II)[259] complexes, may permit reaction under milder conditions, with greater selectivity. Alkenes can undergo Rh(I)-catalyzed hydroboration with pinacolborane **[L17558]**, to give the alkylboronate,[260] or, with a phosphine-free Rh(I) complex, the alkenylboronate[261] by dehydrogenative boronylation. Vinylboronates are also formed from alkynes and pinacolborane (2 eq.) under mild conditions.[262] High yields are obtained with 1 eq. of the reagent in the presence of Rh or Ni catalysts[260] (Scheme 28).



Scheme 28

Transition metal catalyzed B–C coupling

As well as the need for low temperatures, the use of reactive organometallics, RMgX or RLi, as boronic acid precursors is generally limited to substrates lacking functional groups which could react with the organometallic species. A major advance in the synthesis of arylboronic esters came with the publication by Miyaura[263] of the palladium-catalyzed coupling of aryl halides with diboron esters, especially bis(pinacolato)diboron [**L16088**], by cleavage of the B–B bond, enabling access to boronic acid derivatives without protection of functionalities such as ester, ketone, cyano or nitro groups (Scheme 29).



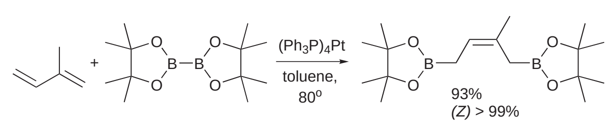
Scheme 29

Aryl triflates are also converted to pinacol arylboronates under similar conditions,[264] as are arenediazonium salts.[265] The reaction has been adapted to boronylation of polymer-supported aryl iodides, allowing *in situ* coupling to give unsymmetrical biaryls.[266] Microwave irradiation has been found to offer dramatic rate enhancements and improved yields in the formation of otherwise difficult electron-rich boronates.[267] In a further detailed examination of the boronylation reaction, Zhang has shown that ligandless $Pd(OAc)_2$ is a highly effective catalyst with advantages of lower cost, ease of work-up, and the ability to couple the boronate *in situ* with a suitable electrophile.[268]

The preparation of pinacolyl arylboronates by palladium-catalyzed coupling of aryl iodides, triflates or, less readily, bromides with pinacolborane has been described by Masuda.[269] In this method, the arene, formed by reduction of the aryl halide, was often found as a significant by-product. This method has been adapted to a one-pot conversion of aryl bromides to unsymmmetrical biaryls via the pinacol boronates.[270] Aryl iodides can also be converted to the pinacol boronates in accepatble yield in a Pd-free, CuI catalyzed reaction, along with a strong base, preferably NaH.[271] Masuda has reported the Pt(0)-catalyzed regio- and stereoselective synthesis of allylboronates from allyl halides and pinacolborane.[272]

Boronylation with bis(pinacolato)diboron, catalyzed by Pd complexes, has been extended to alkenyl halides and triflates,[273,274] benzyl halides[275,276] and allyl acetates.[277] Miyaura has also reported coupling with allyl halides, mediated by copper(I) chloride.[278]

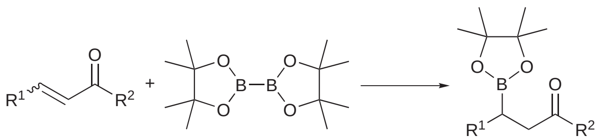
The reaction with alkynes, catalyzed by Pt(0) affords *cis*-bis-boryl alkenes.[279,280] Cu(I)-mediated 1,2-addition to terminal alkynes has also been described.[278] Stereoselective Pt(0)-catalyzed addition to 1,3-dienes gives 1,4-bis-boryl 2-alkenes,[281] (Scheme 30).



Scheme 30

A detailed discussion of diboration reactions with diboron derivatives has been published by Marder and Norman.[282]

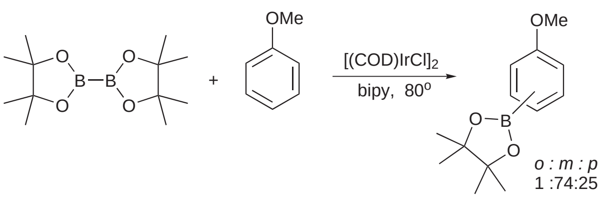
Marder and Norman first reported 1,4-addition of bis(pinacolato)diboron to enones, catalyzed by a Pt(0) complex.[283] Other authors have described a variety conditions for this type of reaction, promoted by Pt(0),[284] Cu(I)[278,285] or Rh(I)[286] systems (Scheme 31).



Conditions: $(C_2H_4)(Ph_3P)_2Pt$, PhMe, 80^o ref 220
$(Ph_3P)_4Pt$, PhMe, 110^o ref 153
CuCl, KOAc, DMF, rt ref 148
CuOTf, n-Bu_3P, DMF, rt ref 154
$(Ph_3P)_3RhCl$, PhMe, 80^o ref 221

Scheme 31

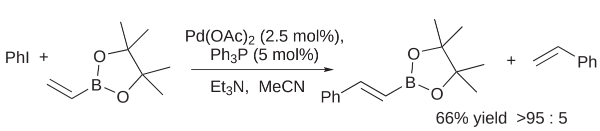
Alkylbenzenes can be boronylated on the side-chain with either bis(pinacolato)diboron or pinacolborane, in the presence of Pd/C catalyst, providing a direct route to benzylboronates.[287] Direct boronylation of aromatic rings has been achieved with pinacolborane in the presence of a rhodium complex,[288] or with bis(pinacolato)diboron with an iridium(I) complex (Scheme 32).[289]



Scheme 32

Vinylboronate reactions

Vinylboronic acid polymerizes too readily for convenient isolation. The pinacol ester [**L19811**], on the other hand, is stable enough to be stored, and can undergo a variety of useful reactions. Whiting has shown that palladium-catalyzed cross-coupling with halides can take place in either Suzuki (loss of boron) or Heck (retention of boron) modes.[126] However, use of the more nucleophilic vinyltrifluoroborate salt [**L17970**] in the Suzuki coupling may be preferable (see Section 3).[125] With the pinacol ester, Whiting has developed reaction conditions which favor the Heck coupling, providing a route to styryl and other 2-substituted vinylboronates (Scheme 33).[290,291]



Scheme 33

Homologated alkenylboronates are available via ruthenium-catalyzed cross-metathesis with terminal alkenes.[292] The olefinic double bond of a vinylboronate can also undergo cycloaddition reactions with 1,3-dipoles, such as isoxazolines from nitrile oxides,[293,294] and various free-radical reactions,[295-297] leading to substituted boronates.

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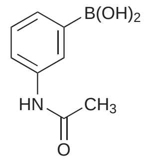
The Alfa Aesar range of boronics

Arylboronic acids

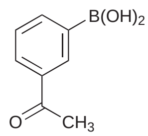
3-Acetamidobenzeneboronic acid, 98%

B23833 [78887-39-5] — 1g, 5g, 25g



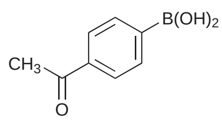
3-Acetylbenzeneboronic acid, 97%

B23478 [204841-19-0] — 1g, 5g, 25g



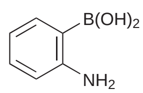
4-Acetylbenzeneboronic acid, 98+%

B23234 [149104-90-5] — 1g, 5g, 25g



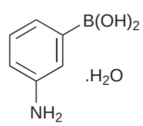
2-Aminobenzeneboronic acid, 96%

L18069 [5570-18-3] — 100mg, 1g, 5g



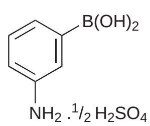
3-Aminobenzeneboronic acid monohydrate, 97%

A18189 [206658-89-1] — 1g, 5g, 25g



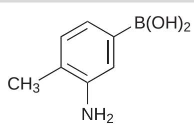
3-Aminobenzeneboronic acid hemisulfate, 98+%

A17240 [66472-86-4] — 1g, 5g, 25g



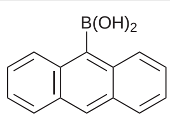
3-Amino-4-methylbenzeneboronic acid, 98%

L17695 [22237-12-3] — 1g, 5g



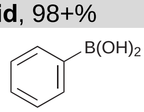
9-Anthraceneboronic acid, 99%

L19630 [100622-34-2] — 100mg, 500mg



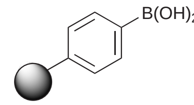
Benzeneboronic acid, 98+%

A14257 [98-80-6] — 10g, 50g, 250g



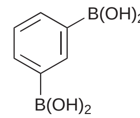
Benzeneboronic acid, polymer-supported, 2.6-3.2 mmol/g

L19459 — 1g, 5g, 25g



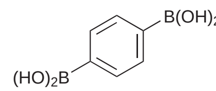
1,3-Benzenediboronic acid, 97%

B24903 [4612-28-6] — 1g, 5g, 25g



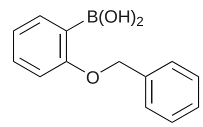
1,4-Benzenediboronic acid, 96%

B24064 [4612-26-4] — 1g, 5g, 25g



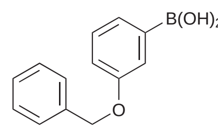
2-Benzyloxybenzeneboronic acid, 96%

L20100 [190661-29-1] — 1g, 5g



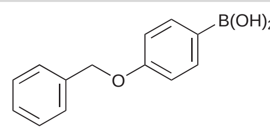
3-Benzyloxybenzeneboronic acid, 98+%

L17474 [156682-54-1] — 1g, 5g



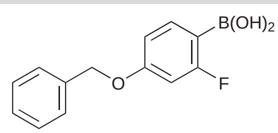
4-Benzyloxybenzeneboronic acid, 97%

B24351 [146631-00-7] — 250mg, 1g, 5g



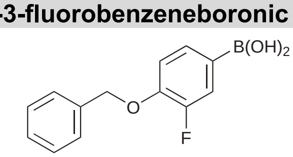
4-Benzyloxy-2-fluorobenzeneboronic acid, 96%

L18521 [166744-78-1] — 250mg, 1g, 5g



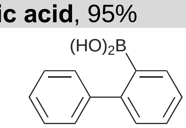
4-Benzyloxy-3-fluorobenzeneboronic acid, 98%

L18520 [133057-83-7] — 250mg, 1g



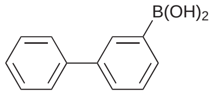
2-Biphenylboronic acid, 95%

L17547 [4688-76-0] — 1g



3-Biphenylboronic acid, 98%

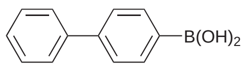
L17552
[5122-95-2]



1g
5g

4-Biphenylboronic acid, 98+%

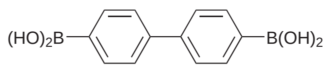
B23703
[156682-54-1]



1g
5g
25g

4,4'-Biphenyldiboronic acid, 97%

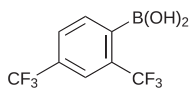
L13328
[4151-80-8]



1g
5g

2,4-Bis(trifluoromethyl)benzeneboronic acid, 97%

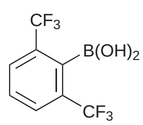
L18161
[153254-09-2]



1g
5g

2,6-Bis(trifluoromethyl)benzeneboronic acid, 97%

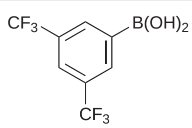
L19952



250mg
1g
5g

3,5-Bis(trifluoromethyl)benzeneboronic acid, 98%

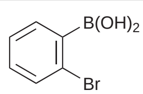
A11373
[73852-19-4]



1g
5g
25g

2-Bromobenzeneboronic acid, 98%

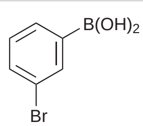
L18581
[244205-40-1]



1g
5g

3-Bromobenzeneboronic acid, 98+%

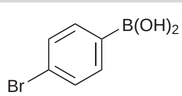
L16354
[89598-96-9]



1g
5g
25g

4-Bromobenzeneboronic acid, 98+%

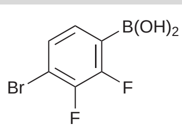
L01565
[5467-74-3]



1g
5g
25g

4-Bromo-2,3-difluorobenzeneboronic acid

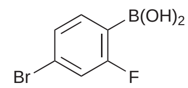
L18516
[374790-99-5]



250mg
1g

4-Bromo-2-fluorobenzeneboronic acid, 95%

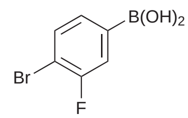
L17468
[216393-64-5]



250mg
1g

4-Bromo-3-fluorobenzeneboronic acid, 98+%

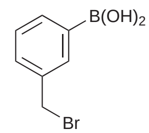
L18514
[374790-97-3]



1g
5g

3-(Bromomethyl)benzeneboronic acid, 95%

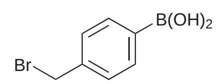
L20102
[51323-43-4]



1g
5g
25g

4-(Bromomethyl)benzeneboronic acid, 94%

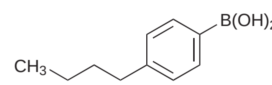
L19953
[68162-47-04]



1g
5g

4-*n*-Butylbenzeneboronic acid, 98%

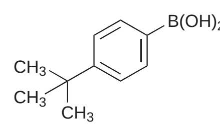
L15584
[145240-28-4]



1g
5g

4-*tert*-Butylbenzeneboronic acid, 97%

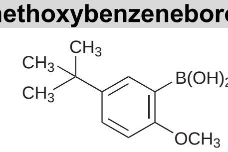
B24408
[123324-71-0]



1g
5g

5-tert-Butyl-2-methoxybenzeneboronic acid

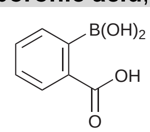
L20415
[128733-85-7]



250mg
1g

2-Carboxybenzeneboronic acid, 95%

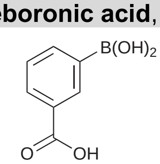
L16301
[149105-19-1]



250mg
1g
5g

3-Carboxybenzeneboronic acid, 98%

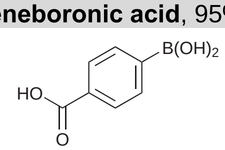
B25315
[25487-66-5]



1g
5g

4-Carboxybenzeneboronic acid, 95%

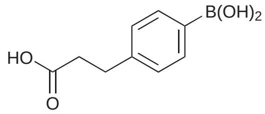
B20954
[14047-29-1]



1g
5g
25g

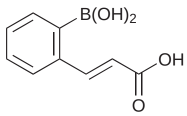
4-(2-Carboxyethyl)benzeneboronic acid, 97%

L17485 [166316-48-9] — 1g, 5g



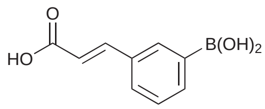
2-(2-Carboxyvinyl)benzeneboronic acid, 98%

L16368 [374105-86-9] — 50mg, 250mg



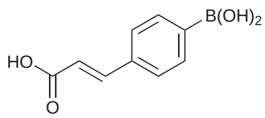
3-(2-Carboxyvinyl)benzeneboronic acid, 97%

L16369 [216144-91-1] — 250mg, 1g



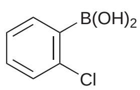
4-(2-Carboxyvinyl)benzeneboronic acid, 95%

L15586 [151169-68-5] — 250mg, 1g, 5g



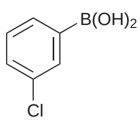
2-Chlorobenzeneboronic acid, 97%

B23324 [3900-89-8] — 1g, 5g, 25g



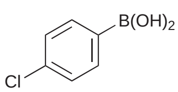
3-Chlorobenzeneboronic acid, 97%

B24444 [63503-60-6] — 1g, 5g, 25g



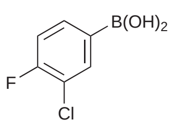
4-Chlorobenzeneboronic acid, 98+%

A15657 [1679-18-1] — 1g, 5g, 25g



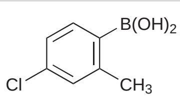
3-Chloro-4-fluorobenzeneboronic acid, 99%

B22755 [144432-85-9] — 1g, 5g, 25g



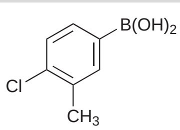
4-Chloro-2-methylbenzeneboronic acid, 98%

B23688 [209919-30-2] — 1g, 5g



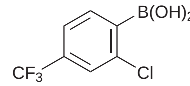
4-Chloro-3-methylbenzeneboronic acid, 98%

B23179 [161950-10-3] — 1g, 5g



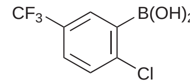
2-Chloro-4-(trifluoromethyl)benzeneboronic acid, 96%

L20103 [254993-59-4] — 1g, 5g



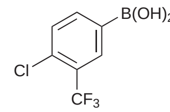
2-Chloro-5-(trifluoromethyl)benzeneboronic acid, 96%

L20104 [182344-18-9] — 1g, 5g



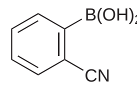
4-Chloro-3-(trifluoromethyl)benzeneboronic acid, 96%

L20105 [176976-42-4] — 1g, 5g



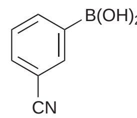
2-Cyanobenzeneboronic acid, 98%

L19676 [138642-62-3] — 1g, 5g



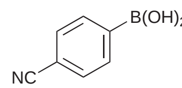
3-Cyanobenzeneboronic acid, 98+%

L19635 [150255-96-2] — 250mg, 1g, 5g



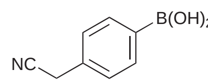
4-Cyanobenzeneboronic acid, 98%

L18007 [126747-14-6] — 1g, 5g



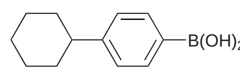
4-(Cyanomethyl)benzeneboronic acid, 98%

L19955 [91983-26-5] — 1g, 5g



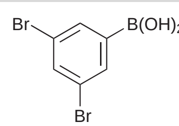
4-Cyclohexylbenzeneboronic acid, 98%

L18076 [374538-04-2] — 250mg, 1g, 5g



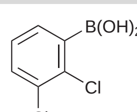
3,5-Dibromobenzeneboronic acid, 97%

B23863 [117695-55-3] — 1g, 5g, 25g



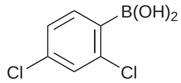
2,3-Dichlorobenzeneboronic acid, 98+%

B22781 [151169-74-3] — 1g, 5g, 25g



2,4-Dichlorobenzeneboronic acid, 98+%

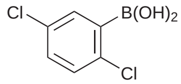
L01563 [68716-47-2]



1g
5g

2,5-Dichlorobenzeneboronic acid, 98+%

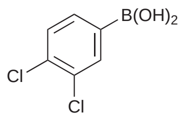
B22984 [135145-90-3]



1g
5g

3,4-Dichlorobenzeneboronic acid, 97%

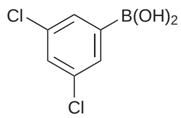
B24292 [151169-75-4]



1g
5g
25g

3,5-Dichlorobenzeneboronic acid, 98+%

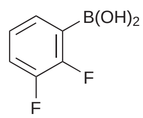
B22765 [67492-50-6]



1g
5g
25g

2,3-Difluorobenzeneboronic acid, 98%

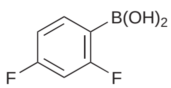
L18012 [121219-16-7]



1g
5g
25g

2,4-Difluorobenzeneboronic acid, 97%

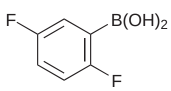
B23821 [144025-03-6]



1g
5g
25g

2,5-Difluorobenzeneboronic acid, 96%

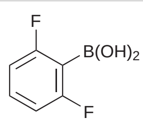
B24113 [193353-34-3]



1g
5g
25g

2,6-Difluorobenzeneboronic acid, 98%

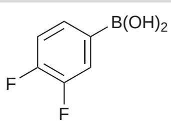
B22805 [162101-25-9]



1g
5g
25g

3,4-Difluorobenzeneboronic acid, 98%

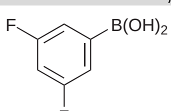
B22799 [168267-41-2]



1g
5g
25g

3,5-Difluorobenzeneboronic acid, 98+%

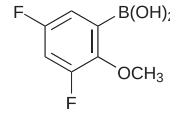
L17425 [156545-07-2]



1g
5g

3,5-Difluoro-2-methoxybenzeneboronic acid, 97%

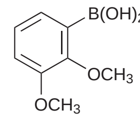
L19773



250mg
1g
5g

2,3-Dimethoxybenzeneboronic acid, 98%

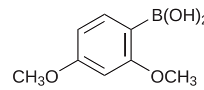
B24125 [40972-86-9]



1g
5g
25g

2,4-Dimethoxybenzeneboronic acid, 98%

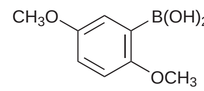
B24374 [133730-34-4]



1g
5g
25g

2,5-Dimethoxybenzeneboronic acid, 98%

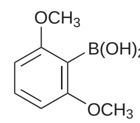
B24571 [107099-99-0]



1g
5g
25g

2,6-Dimethoxybenzeneboronic acid, 98%

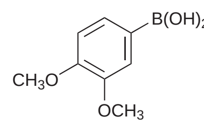
B24305 [23112-96-1]



1g
5g
25g

3,4-Dimethoxybenzeneboronic acid, 98%

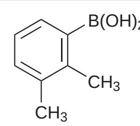
B24240 [122775-35-3]



1g
5g
25g

2,3-Dimethylbenzeneboronic acid, 98%

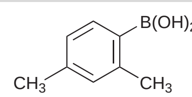
B23942 [183158-34-1]



1g
5g
25g

2,4-Dimethylbenzeneboronic acid, 97%

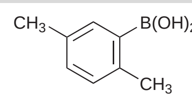
B23076 [55499-44-0]



1g
5g
25g

2,5-Dimethylbenzeneboronic acid, 95%

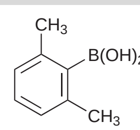
B23740 [85199-06-0]



1g
5g
25g

2,6-Dimethylbenzeneboronic acid, 97%

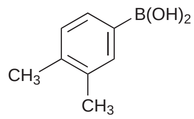
B24613 [100379-00-8]



1g
5g
25g

3,4-Dimethylbenzeneboronic acid, 98+%

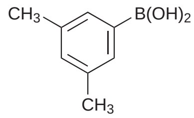
L17461
[55499-43-9]



1g
5g

3,5-Dimethylbenzeneboronic acid, 98%

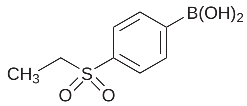
B23434
[172975-69-8]



1g
5g
25g

4-(Ethanesulfonyl)benzeneboronic acid, 98+%

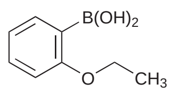
L17814
[352530-24-6]



250mg
1g

2-Ethoxybenzeneboronic acid, 98%

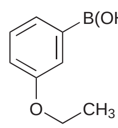
B23644
[213211-69-9



1g
5g
25g

3-Ethoxybenzeneboronic acid

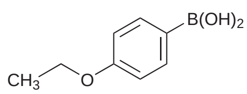
B24485
[90555-66-1]



1g
5g
25g

4-Ethoxybenzeneboronic acid, 98%

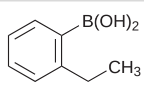
L23683
[22237-13-4]



1g
5g
25g

2-Ethylbenzeneboronic acid, 98+%

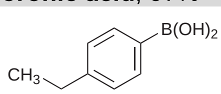
L17719
[90002-36-1]



1g
5g

4-Ethylbenzeneboronic acid, 97%

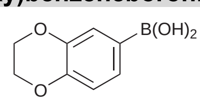
B24656
[63139-21-9]



1g
5g
25g

3,4-(Ethylenedioxy)benzeneboronic acid, 97%

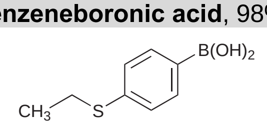
L20296
[164014-95-3]



1g
5g

4-(Ethylthio)benzeneboronic acid, 98%

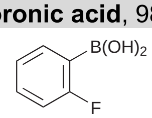
L17623
[145349-76-4]



1g
5g

2-Fluorobenzeneboronic acid, 98%

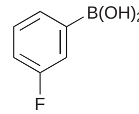
B23103
[1993-03-9]



1g
5g
25g

3-Fluorobenzeneboronic acid, 97%

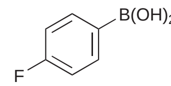
B21247
[768-35-4]



1g
5g
25g

4-Fluorobenzeneboronic acid, 98%

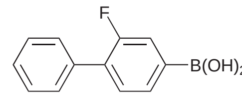
A15991
[1765-93-1]



1g
5g
25g

2-Fluorobiphenyl-4-boronic acid, 97%

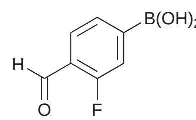
L15634
[178305-99-2]



1g
5g

3-Fluoro-4-formylbenzeneboronic acid, 98%

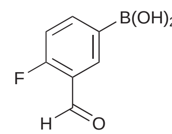
L17851
[248270-25-9]



1g

4-Fluoro-3-formylbenzeneboronic acid, 98+%

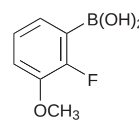
L17808
[374538-01-9]



250mg
1g

2-Fluoro-3-methoxybenzeneboronic acid, 97%

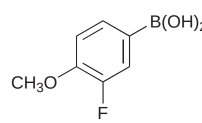
L19655
[352303-67-4]



1g
5g

3-Fluoro-4-methoxybenzeneboronic acid, 98+%

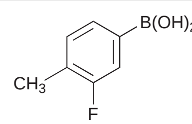
L19818
[149507-26-6]



1g
5g

3-Fluoro-4-methylbenzeneboronic acid, 98%

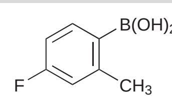
B24512
[168267-99-0]



1g
5g
25g

4-Fluoro-2-methylbenzeneboronic acid, 98%

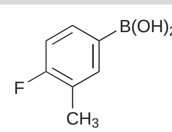
B24117
[139911-29-8]



1g
5g
25g

4-Fluoro-3-methylbenzeneboronic acid, 98%

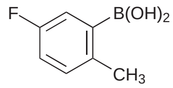
L18753
[139911-27-6]



1g
5g

5-Fluoro-2-methylbenzeneboronic acid, 99%

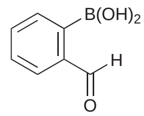
L19819
[163517-62-2]



1g
5g

2-Formylbenzeneboronic acid, 97%

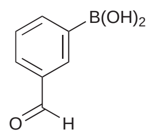
B25434
[40138-16-7]



1g
5g

3-Formylbenzeneboronic acid, 98%

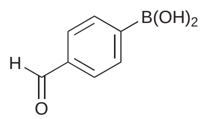
B25437
[87199-16-4]



1g
5g
25g

4-Formylbenzeneboronic acid, 97%

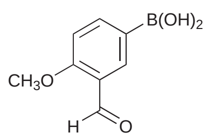
B25199
[87199-17-5]



1g
5g
25g

3-Formyl-4-methoxybenzeneboronic acid, 98%

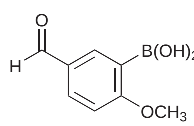
L17850
[121124-97-8]



1g
5g

5-Formyl-2-methoxybenzeneboronic acid, 98%

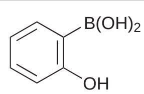
L19059
[127972-02-5]



250mg
1g
5g

2-Hydroxybenzeneboronic acid, 97%

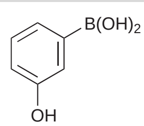
L19400
[89466-08-0]



1g
5g

3-Hydroxybenzeneboronic acid, 97%

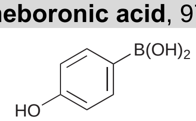
L19061
[87199-18-6]



1g
5g

4-Hydroxybenzeneboronic acid, 97%

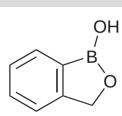
L15594
[71597-85-8]



1g
5g

2-(Hydroxymethyl)benzeneboronic acid hemiester, 98+%

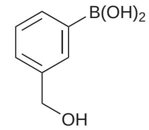
L15192
[5735-41-1]



250mg
1g

3-(Hydroxymethyl)benzeneboronic acid, 94%

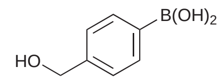
L15193
[87199-15-3]



1g
5g

4-(Hydroxymethyl)benzeneboronic acid, 98%

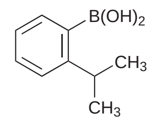
L15194
[59016-93-2]



1g
5g
25g

2-Isopropylbenzeneboronic acid, 97%

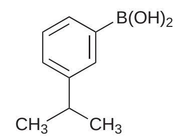
L20110
[89787-12-2]



250mg
1g
5g

3-Isopropylbenzeneboronic acid, 99%

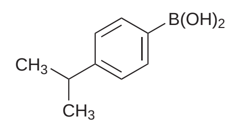
L15530
[216019-28-2]



250mg
1g
5g

4-Isopropylbenzeneboronic acid, 98+%

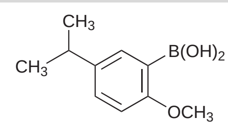
L17459
[16152-51-5]



1g
5g

5-Isopropyl-2-methoxybenzeneboronic acid, 98+%

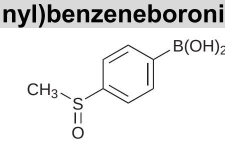
L17460
[216393-63-4]



1g
5g

4-(Methanesulfinyl)benzeneboronic acid, 98%

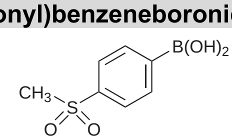
L17865
[166386-48-7]



100mg
1g

4-(Methanesulfonyl)benzeneboronic acid, 98%

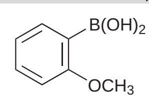
L17720
[149104-88-1]



250mg
1g
5g

2-Methoxybenzeneboronic acid, 97%

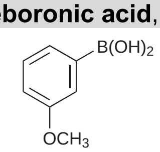
B21071
[5720-06-9]



1g
5g
25g

3-Methoxybenzeneboronic acid, 97%

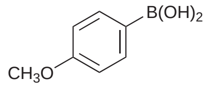
B24412
[10365-98-7]



1g
5g
25g

4-Methoxybenzeneboronic acid, 98%

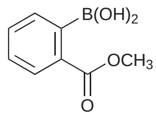
A14462
[5720-07-0]



1g
5g
25g

2-(Methoxycarbonyl)benzeneboronic acid, 97%

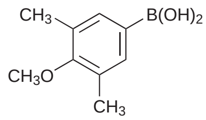
L17958
[374538-03-1]



250mg
1g
5g

4-Methoxy-3,5-dimethylbenzeneboronic acid, 99%

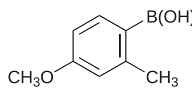
L19820
[301699-39-8]



1g
5g

4-Methoxy-2-methylbenzeneboronic acid, 98%

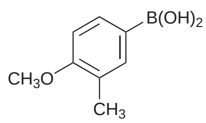
L20112
[208399-66-0]



1g
5g

4-Methoxy-3-methylbenzeneboronic acid, 98+%

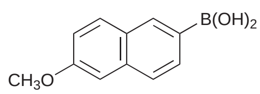
L19821
[175883-62-2]



1g
5g

6-Methoxy-2-naphthaleneboronic acid, 95%

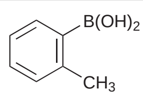
L19060
[156641-98-4]



1g
5g

2-Methylbenzeneboronic acid, 98%

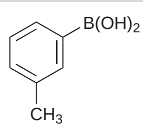
B23154
[16419-60-6]



1g
5g
25g

3-Methylbenzeneboronic acid, 97%

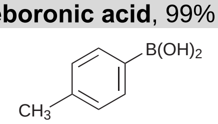
B23025
[17933-03-8]



1g
5g
25g

4-Methylbenzeneboronic acid, 99%

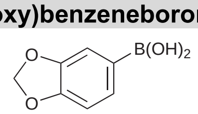
A13347
[5720-05-8]



1g
5g
25g

3,4-(Methylenedioxy)benzeneboronic acid, 98%

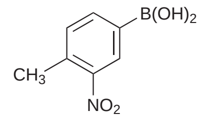
B24217
[94839-07-3]



1g
5g

4-Methyl-3-nitrobenzeneboronic acid, 98%

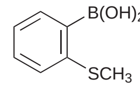
L17052
[80500-27-2]



1g
5g

2-(Methylthio)benzeneboronic acid, 98+%

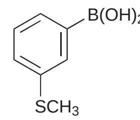
L17456
[168618-42-6]



1g
5g

3-(Methylthio)benzeneboronic acid, 97%

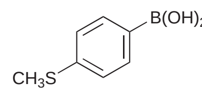
L20250
[128312-11-8]



250mg
1g
5g

4-(Methylthio)benzeneboronic acid, 97%

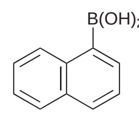
B23454
[98546-51-1]



1g
5g
25g

1-Naphthaleneboronic acid, 96%

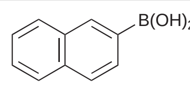
B21219
[13922-41-3]



1g
5g
25g

2-Naphthaleneboronic acid, 97%

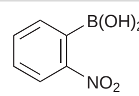
B24157
[32316-92-0]



1g
5g
25g

2-Nitrobenzeneboronic acid, 96%

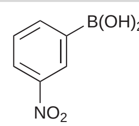
L17988
[5570-19-4]



1g
5g

3-Nitrobenzeneboronic acid, 98%

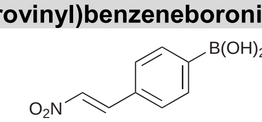
A13336
[13331-27-6]



1g
5g
25g

***trans*-4-(β-Nitrovinyl)benzeneboronic acid**, 97%

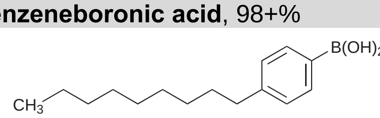
L17004
[216394-04-6]



250mg
1g

4-*n*-Nonylbenzeneboronic acid, 98+%

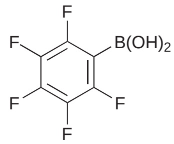
L17753
[256383-45-6]



1g
5g

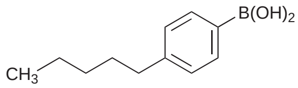
2,3,4,5,6-Pentafluorobenzeneboronic acid, 97%

B22922 [1582-24-7] — 5g, 25g



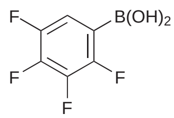
4-*n*-Pentylbenzeneboronic acid, 97%

L18011 [121219-12-3] — 250mg, 1g, 5g



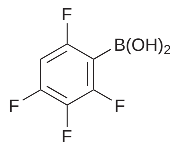
2,3,4,5-Tetrafluorobenzeneboronic acid, 98%

L19824 [179923-32-1] — 250mg, 1g



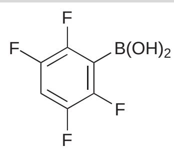
2,3,4,6-Tetrafluorobenzeneboronic acid

L19825 — 250mg, 1g



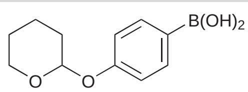
2,3,5,6-Tetrafluorobenzeneboronic acid, 99%

L19826 — 1g



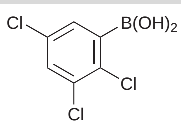
4-(Tetrahydro-2H-pyran-2-yloxy)benzeneboronic acid

H50445 [182281-01-2] — 250mg, 1g



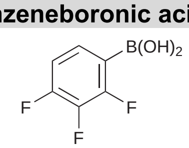
2,3,5-Trichlorobenzeneboronic acid, 98%

L17511 [212779-19-6] — 1g, 5g



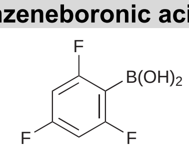
2,3,4-Trifluorobenzeneboronic acid

L19827 [226396-32-3] — 250mg, 1g



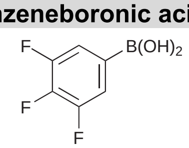
2,4,6-Trifluorobenzeneboronic acid, 97%

L19402 [182482-25-3] — 1g, 5g



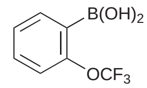
3,4,5-Trifluorobenzeneboronic acid, 97%

L18519 [143418-49-9] — 250mg, 1g



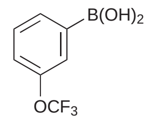
2-(Trifluoromethoxy)benzeneboronic acid, 98%

L19774 [175676-65-0] — 250mg, 1g



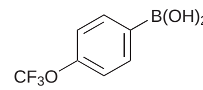
3-(Trifluoromethoxy)benzeneboronic acid, 98%

L19775 [179113-90-7] — 1g, 5g



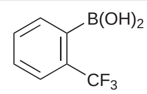
4-(Trifluoromethoxy)benzeneboronic acid, 98%

B23233 [139301-27-2] — 1g, 5g, 25g



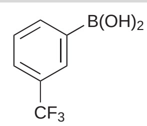
2-(Trifluoromethyl)benzeneboronic acid, 97%

B24343 [1423-27-4] — 1g, 5g, 25g



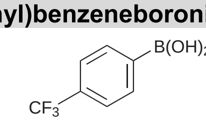
3-(Trifluoromethyl)benzeneboronic acid, 98%

B21661 [1423-26-3] — 1g, 5g, 25g



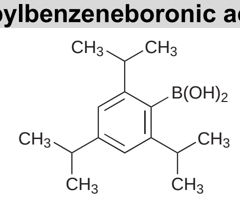
4-(Trifluoromethyl)benzeneboronic acid, 98%

B22374 [128796-39-4] — 1g, 5g, 25g



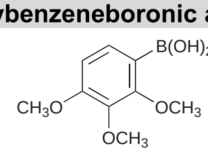
2,4,6-Triisopropylbenzeneboronic acid, 98%

B22891 [154549-38-9] — 1g, 5g, 25g



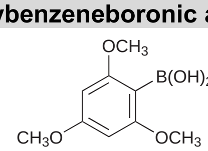
2,3,4-Trimethoxybenzeneboronic acid, 98%

L19838 [118062-05-8] — 1g, 5g



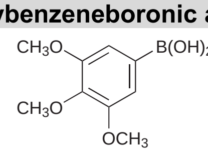
2,4,6-Trimethoxybenzeneboronic acid, 98%

L19837 [135159-25-0] — 1g, 5g



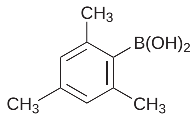
3,4,5-Trimethoxybenzeneboronic acid, 98+%

L15191 [182163-96-8] — 1g, 5g



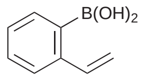
2,4,6-Trimethylbenzeneboronic acid, 97%

B24060 1g
[5980-97-2] 5g



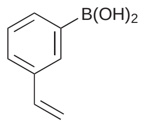
2-Vinylbenzeneboronic acid, 98%

L19828 250mg
[15016-42-9] 1g



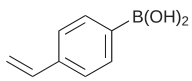
3-Vinylbenzeneboronic acid, 98%

L19829 250mg
[15016-43-0] 1g



4-Vinylbenzeneboronic acid, 98%

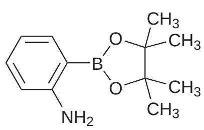
B23709 1g
[2156-04-9] 5g



Arylboronic esters

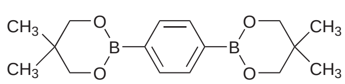
2-Aminobenzeneboronic acid pinacol ester

L19951 1g
[191171-55-8] 5g



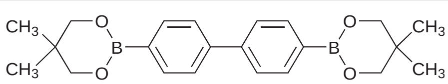
1,4-Benzenediboronic acid bis(neopentyl glycol) ester, 99%

L16187 250mg
[5565-36-6] 1g
5g



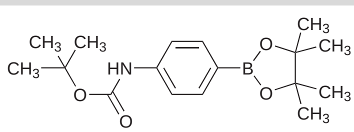
4,4'-Biphenyldiboronic acid bis(neopentyl glycol) ester, 98%

L17605 1g
[5487-93-4] 5g



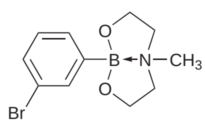
4-(Boc-amino)benzeneboronic acid pinacol ester, 98%

L19653 1g
[330793-01-6] 5g



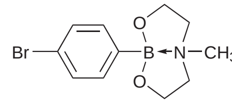
3-Bromobenzeneboronic acid N-methyldiethanolamine ester, 98%

L17796 1g
[374538-00-8] 5g



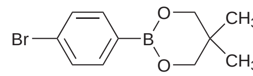
4-Bromobenzeneboronic acid N-methyldiethanolamine ester, 98%

L17775 250mg
[133468-58-3] 1g



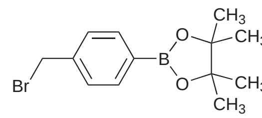
4-Bromobenzeneboronic acid neopentyl glycol ester, 98+%

L17455 1g
[183677-71-6] 5g



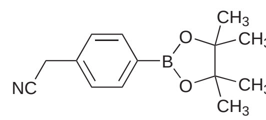
4-(Bromomethyl)benzeneboronic acid pinacol ester, 97%

L19954 1g
[138500-85-3] 5g



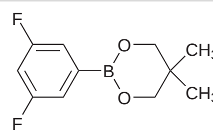
4-(Cyanomethyl)benzeneboronic acid pinacol ester, 95%

L19956 1g
[138500-86-4] 5g



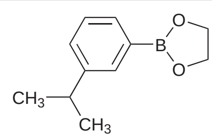
3,5-Difluorobenzeneboronic acid neopentyl glycol ester, 98+%

L17266 1g
[216393-57-6] 5g



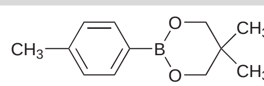
3-Isopropylbenzeneboronic acid ethylene glycol ester, 96%

L17670 250mg
[374537-96-9] 1g



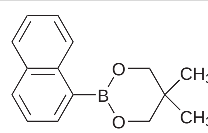
4-Methylbenzeneboronic acid neopentyl glycol ester, 99%

L19563 1g
[380481-66-3] 5g
25g



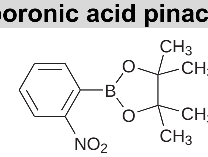
1-Naphthaleneboronic acid neopentyl glycol ester, 98%

L17612 1g
[22871-77-8] 5g



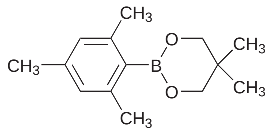
2-Nitrobenzeneboronic acid pinacol ester, 98+%

L19963 1g
[190788-59-1] 5g



2,4,6-Trimethylbenzeneboronic acid neopentyl glycol ester, 99%

L17232
[214360-78-8]

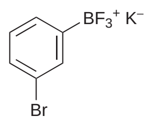


1g
5g

Aryltrifluoroborate salts

Potassium 3-bromophenyltrifluoroborate, 97%

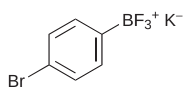
L17966
[374564-34-8]



1g
5g

Potassium 4-bromophenyltrifluoroborate, 97%

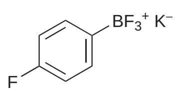
L17967
[374564-35-9]



1g
5g

Potassium 4-fluorophenyltrifluoroborate, 98%

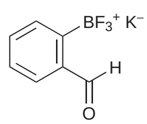
L17655
[192863-35-7]



1g
5g

Potassium 2-formylphenyltrifluoroborate

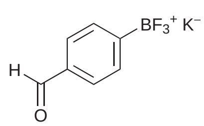
L17968
[192863-39-1]



1g

Potassium 4-formylphenyltrifluoroborate

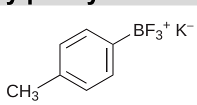
L17969
[374564-36-0]



1g
5g

Potassium 4-methylphenyltrifluoroborate, 98%

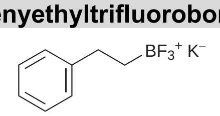
L17604
[216434-82-1]



1g
5g

Potassium 2-phenyethyltrifluoroborate, 98%

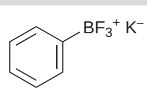
H25930
[329976-74-1]



1g
5g

Potassium phenyltrifluoroborate, 98%

L17568
[153766-81-5]

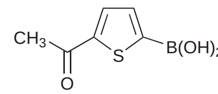


1g
5g

Heteroaryl boronic acids

5-Acetylthiophene-2-boronic acid, 98%

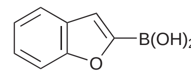
L15221
[206551-43-1]



1g
5g
25g

Benzo[b]furan-2-boronic acid, 98%

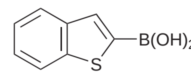
B23676
[98437-24-2]



1g
5g
25g

Benzo[b]thiophene-2-boronic acid, 98%

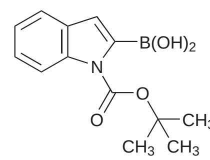
B22835
[98437-23-1]



1g
5g
25g

1-Boc-indole-2-boronic acid, 95%

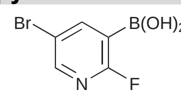
L18009
[213318-44-6]



250mg
1g
5g

5-Bromo-2-fluoropyridine-3-boronic acid, 98%

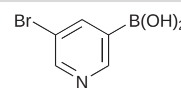
L19915
[501435-91-2]



250mg
1g
5g

5-Bromopyridine-3-boronic acid, 95%

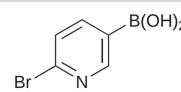
L20084
[452972-09-7]



250mg
1g
5g

6-Bromopyridine-3-boronic acid, 95%

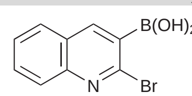
L20085
[223463-14-7]



250mg
1g
5g

2-Bromoquinoline-3-boronic acid, 97%

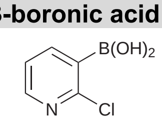
L20327



250mg
1g
5g

2-Chloropyridine-3-boronic acid, 96%

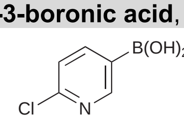
L20303
[381248-04-0]



1g
5g

6-Chloropyridine-3-boronic acid, 96%

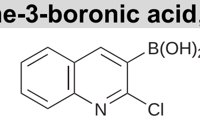
L20388
[444120-91-6]



250mg
1g
5g

2-Chloroquinoline-3-boronic acid, 97%

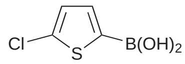
L20329
[128676-84-6]



250mg
1g
5g

5-Chlorothiophene-2-boronic acid, 97%

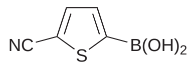
B23193
[162607-18-3]



1g
5g
25g

5-Cyanothiophene-2-boronic acid, 98%

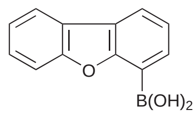
L18523
[305832-67-1]



250mg
1g

Dibenzofuran-4-boronic acid, 98+%

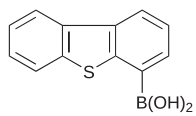
L19830
[100124-06-9]



1g
5g

Dibenzothiophene-4-boronic acid

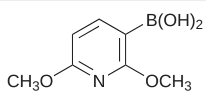
L19831
[108847-20-7]



1g
5g

2,6-Dimethoxypyridine-3-boronic acid, 95%

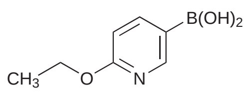
L20389
[444120-91-6]



250mg
1g
5g

6-Ethoxypyridine-3-boronic acid, 98%

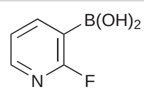
L20398
[612845-44-0]



250mg
1g
5g

2-Fluoropyridine-3-boronic acid, 97%

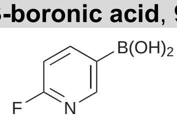
L20108
[174669-73-9]



1g
5g

6-Fluoropyridine-3-boronic acid, 98%

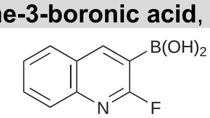
L20387
[351019-18-6]



250mg
1g
5g

2-Fluoroquinoline-3-boronic acid, 97%

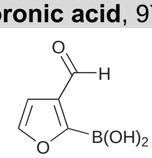
L20341
[745784-10-5]



250mg
1g
5g

3-Formylfuran-2-boronic acid, 97%

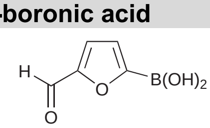
L15198
[27339-38-4]



1g
5g

5-Formylfuran-2-boronic acid

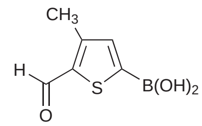
L17920
[27329-70-0]



250mg
1g
5g

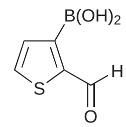
5-Formyl-4-methylthiophene-2-boronic acid

H25947
[352530-25-7]



2-Formylthiophene-3-boronic acid, 97%

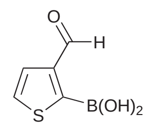
L15195
[4347-31-3]



1g
5g

3-Formylthiophene-2-boronic acid, 97%

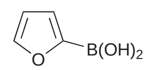
L15196
[17303-83-2]



1g
5g

Furan-2-boronic acid, 97%

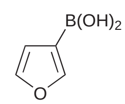
B23842
[13331-23-2]



1g
5g
25g

Furan-3-boronic acid, 97%

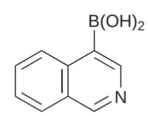
L19834
[55552-70-0]



1g
5g

Isoquinoline-4-boronic acid, 97%

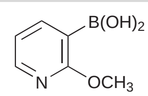
L20430
[192182-56-2]



250mg
1g
5g

2-Methoxypyridine-3-boronic acid, 98%

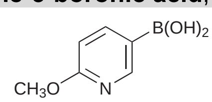
L20094
[163105-90-6]



1g
5g

6-Methoxypyridine-3-boronic acid, 98%

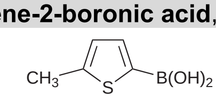
L20087
[163105-89-3]



250mg
1g
5g

5-Methylthiophene-2-boronic acid, 98%

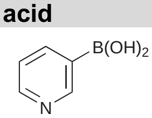
B23138
[162607-20-7]



1g
5g

Pyridine-3-boronic acid

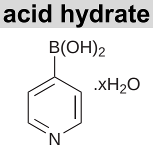
L15040
[1692-25-7]



1g
5g

Pyridine-4-boronic acid hydrate

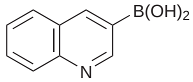
L15179
[1692-15-5]



1g
5g

Quinoline-3-boronic acid, 95%

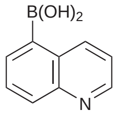
L20088
[191162-39-7]



250mg
1g
5g

Quinoline-5-boronic acid, 97%

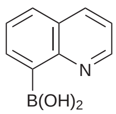
L19639
[355386-94-6]



250mg
1g

Quinoline-8-boronic acid, 99%

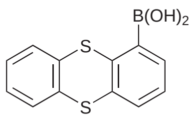
L19640
[86-58-8]



250mg
1g

Thianthrene-1-boronic acid, tech. 90%

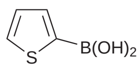
L19833
[108847-76-3]



1g
5g

Thiophene-2-boronic acid, 98+%

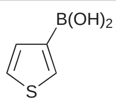
B23071
[6165-68-0]



1g
5g
25g

Thiophene-3-boronic acid, 98%

B23637
[6165-69-1]

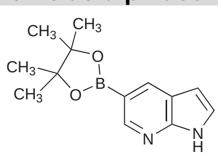


1g
5g

Heteroaryl boronic esters

7-Azaindole-5-boronic acid pinacol ester

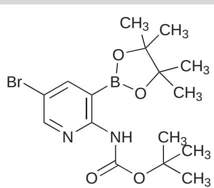
H50015
[754214-56-7]



250mg
1g

2-(Boc-amino)pyridine-3-boronic acid pinacol ester

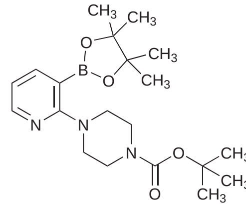
H50094



250mg
1g

2-(4-Boc-1-piperazino)pyridine-3-boronic acid pinacol ester

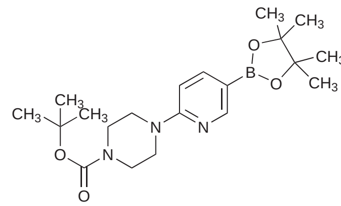
H50058



1g
5g

6-(4-Boc-1-piperazino)pyridine-3-boronic acid pinacol ester

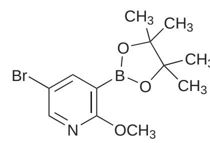
H50145
[496786-98-2]



250mg
1g

5-Bromo-2-methoxypyridine-3-boronic acid pinacol ester

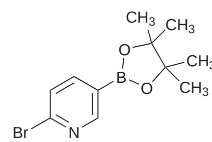
H50064



250mg
1g

6-Bromopyridine-3-boronic acid pinacol ester

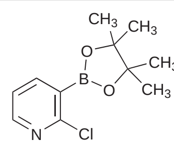
H50072
[214360-62-0]



1g
5g

2-Chloropyridine-3-boronic acid pinacol ester

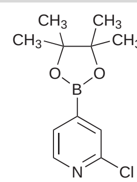
H50053
[452972-11-1]



1g
5g

2-Chloropyridine-4-boronic acid pinacol ester

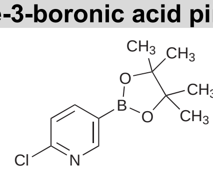
H50070
[458532-84-8]



1g
5g

6-Chloropyridine-3-boronic acid pinacol ester

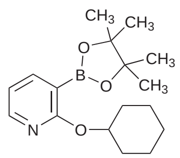
H500071
[444120-94-9]



1g
5g

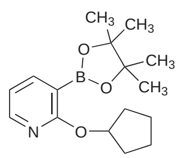
2-(Cyclohexyloxy)pyridine-3-boronic acid pinacol ester

H50111 1g, 5g



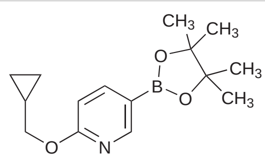
2-(Cyclopentyloxy)pyridine-3-boronic acid pinacol ester

H50110 1g, 5g



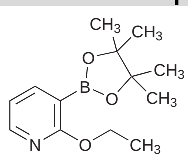
6-(Cyclopropylmethoxy)pyridine-3-boronic acid pinacol ester

H50139 250mg, 1g



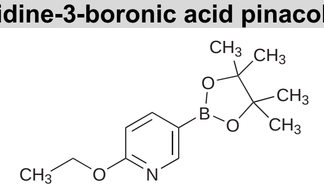
2-Ethoxypyridine-3-boronic acid pinacol ester

H50096 1g, 5g
[848243-23-2]



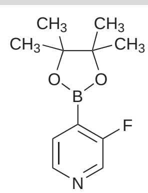
6-Ethoxypyridine-3-boronic acid pinacol ester

H50137 250mg, 1g



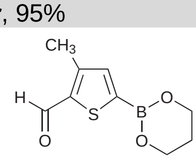
3-Fluoropyridine-4-boronic acid pinacol ester

H50069 250mg, 1g
[458532-88-2]



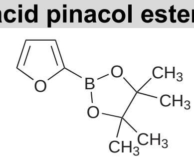
5-Formyl-4-methylthiophene-2-boronic acid 1,3-propanediol ester, 95%

L17779 250mg, 1g
[374537-98-1]



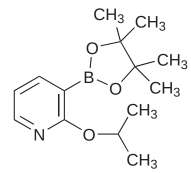
Furan-2-boronic acid pinacol ester, 98%

L18366 1g, 5g
[374790-93-9]



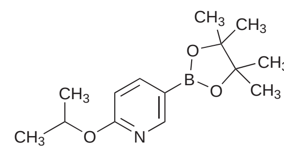
2-Isopropoxypyridine-3-boronic acid pinacol ester

H50097 1g, 5g
[848243-25-4]



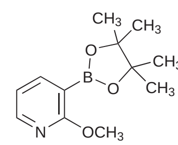
6-Isopropoxypyridine-3-boronic acid pinacol ester

H50141 250mg, 1g
[871839-91-7]



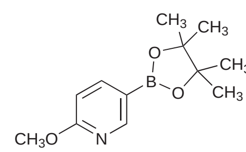
2-Methoxypyridine-3-boronic acid pinacol ester

H50060 250mg, 1g
[532391-32-4]



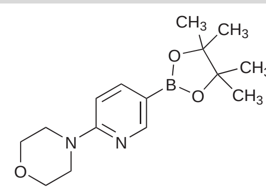
6-Methoxypyridine-3-boronic acid pinacol ester

H50136 250mg, 1g
[445264-61-9]



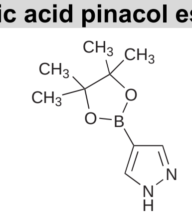
6-(4-Morpholino)pyridine-3-boronic acid pinacol ester

H50143 250mg, 1g



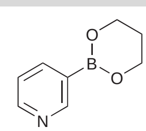
Pyrazole-4-boronic acid pinacol ester, 98%

L19654 1g, 5g
[269410-08-4]



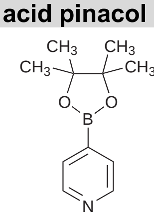
Pyridine-3-boronic acid 1,3-propanediol ester, 98+%

L17010 250mg, 1g, 5g
[131534-65-1]



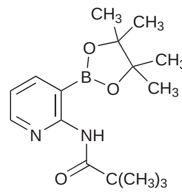
Pyridine-4-boronic acid pinacol ester, 98%

L17854 250mg, 1g
[181219-01-2]



2-(2,2,2-Trimethylacetamido)pyridine-3-boronic acid pinacol ester

H50015
[532391-30-3]

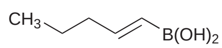


250mg
1g

Alkenylboronic acid

1-Pentenylboronic acid, 98%

L19677
[104376-24-1]

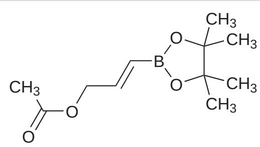


250mg
1g
5g

Alkenylboronic esters

3-Acetoxy-1-propenylboronic acid pinacol ester, 97%

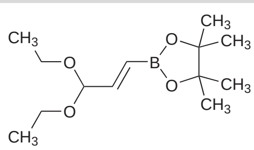
L19700
[161395-97-7]



250mg
1g

3,3-Diethoxy-1-propenylboronic acid pinacol ester, 97%

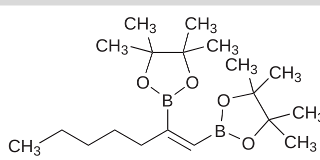
L19579
[153737-25-8]



250mg
1g

***(E)*-1-Heptene-1,2-diboronic acid bis(pinacol) ester**, 98%

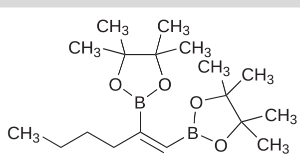
L19649
[307531-74-4]



1g
5g

***(E)*-1-Hexene-1,2-diboronic acid bis(pinacol) ester**, 98%

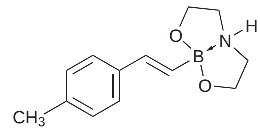
L19650
[185427-48-9]



1g
5g

4-Methyl-β-styrylboronic acid diethanolamine ester, 98+%

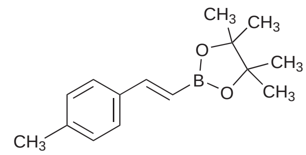
L19704
[608534-31-2]



100mg

4-Methyl-β-styrylboronic acid pinacol ester, 98%

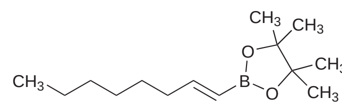
L19698
[149777-84-4]



250mg
1g

1-Octenylboronic acid pinacol ester, 97%

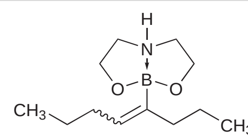
L19697
[170942-79-7]



250mg
1g

4-Octenylboronic acid diethanolamine ester, 98+%

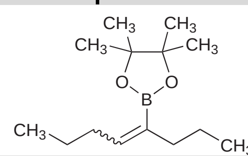
L19705
[608534-40-3]



100mg

4-Octenylboronic acid pinacol ester, 98%

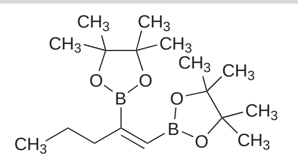
L19699
[177949-95-0]



250mg
1g

***(E)*-1-Pentene-1,2-diboronic acid bis(pinacol) ester**, 98%

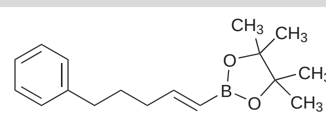
L19648
[177949-95-0]



1g
5g

5-Phenyl-1-pentenylboronic acid pinacol ester, 96%

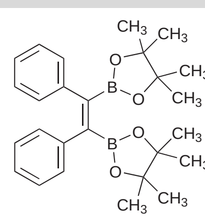
L19701
[154820-97-0]



250mg
1g

***(E)*-Stilbenediboronic acid bis(pinacol ester)**, 98%

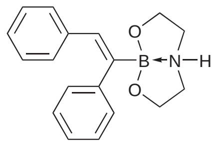
L19652
[151416-94-3]



1g
5g

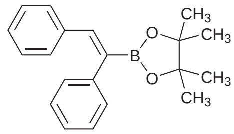
***cis*-Stilbeneboronic acid diethanolamine ester**, 98%

L19573 [501014-42-2] — 100mg



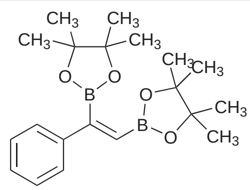
***cis*-Stilbeneboronic acid pinacol ester**, 99%

L19576 [264144-59-4] — 250mg, 1g



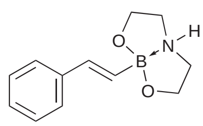
***(E)*-α,β-Styrenediboronic acid bis(pinacol) ester**, 98%

L19651 [173603-23-1] — 1g, 5g



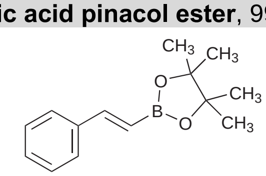
β-Styrylboronic acid diethanolamine ester, 99%

L19571 [411222-52-1] — 100mg



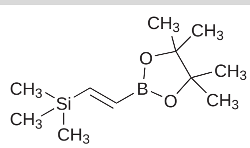
β-Styrylboronic acid pinacol ester, 99%

L19529 [78782-27-1] — 250mg, 1g



2-(Trimethylsilyl)vinylboronic acid pinacol ester, 95%

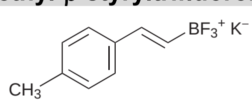
L19577 [126688-99-1] — 250mg, 1g



Alkenyltrifluoroborate salts

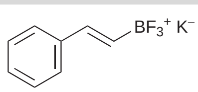
Potassium 4-methyl-β-styryltrifluoroborate

L17973 [219718-86-2] — 1g, 5g



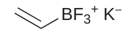
Potassium β-styryltrifluoroborate

L17971 [201852-49-5] — 1g, 5g



Potassium vinyltrifluoroborate, 97%

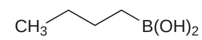
L17970 [13682-77-4] — 1g, 5g



Alkylboronic acids

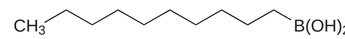
***n*-Butylboronic acid**, 96%

A13725 [4426-47-5] — 1g, 5g, 25g



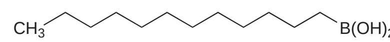
***n*-Decylboronic acid**

L19957 [24464-63-9] — 1g, 5g, 25g



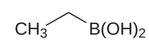
***n*-Dodecylboronic acid**

L19958 [24464-63-9] — 1g, 5g, 25g



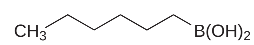
Ethylboronic acid, 98%

L19959 [4433-63-0] — 1g, 5g, 25g



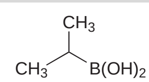
***n*-Hexylboronic acid**, 98%

B22446 [16343-08-1] — 1g, 5g, 25g



Isopropylboronic acid, 98%

L19962 [80041-89-0] — 1g, 5g, 25g



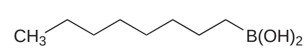
Methylboronic acid, 97%

L15589 [13061-96-6] — 1g, 5g

$CH_3B(OH)_2$

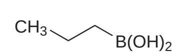
***n*-Octylboronic acid**, 97%

L19964 [28741-08-4] — 1g, 5g, 25g



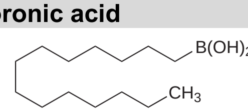
***n*-Propylboronic acid**, 98%

L19965 [17745-45-8] — 1g, 5g, 25g



***n*-Tetradecylboronic acid**

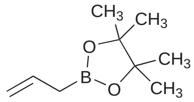
L19966 [100888-40-2] — 1g, 5g, 25g



Alkylboronic esters

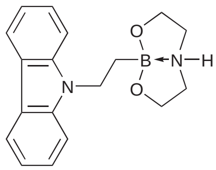
Allylboronic acid pinacol ester, 98+%

L16232 1g 5g
[72824-04-5]



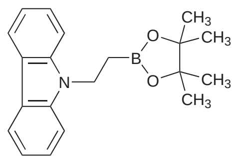
2-(9*H*-Carbazolyl)ethylboronic acid diethanolamine ester, 98%

L19575 100mg
[501014-45-5]



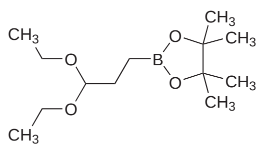
2-(9*H*-Carbazolyl)ethylboronic acid pinacol ester, 98%

L19580 250mg 1g
[608534-41-4]



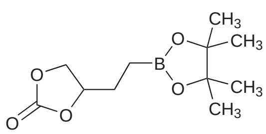
3,3-Diethoxy-1-propylboronic acid pinacol ester, 97%

L19532 250mg 1g
[165904-27-8]



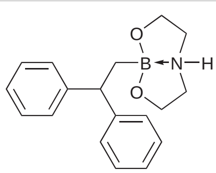
2-(1,3-Dioxolan-2-on-4-yl)-1-ethylboronic acid pinacol ester, 97%

L19533 250mg 1g
[501014-47-7]



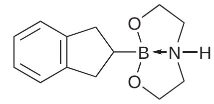
2,2-Diphenyl-1-ethylboronic acid diethanolamine ester, 98+%

L19703 100mg
[608534-43-6]



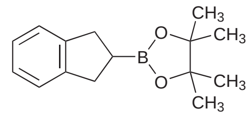
2-Indanylboronic acid diethanolamine ester, 98%

L19574 100mg
[501014-44-4]



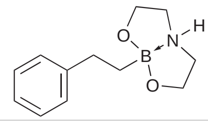
2-Indanylboronic acid pinacol ester, 96%

L19535 250mg 1g
[608534-44-7]



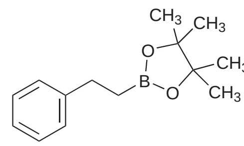
2-Phenylethyl-1-boronic acid diethanolamine ester, 98+%

L19706 100mg
[4848-04-8]



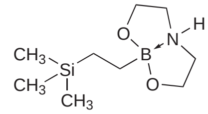
2-Phenylethyl-1-boronic acid pinacol ester, 99%

L19530 250mg 1g
[165904-22-3]



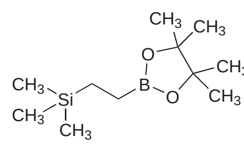
2-Trimethylsilyl-1-ethylboronic acid diethanolamine ester, 98%

L19572 100mg
[501014-43-3]



2-Trimethylsilyl-1-ethylboronic acid pinacol ester, 97%

L19534 250mg 1g
[165904-22-3]



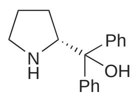
Other products

Selected Alfa Aesar products with applications in boronic acid chemistry. Most are referred to in the text of this publication.

Oxazaborolidine reagents

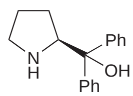
(R)-(+)-α,α-Diphenylprolinol, 99%

L09218 250mg 1g
[22348-32-9]



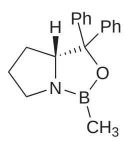
(S̃)-(-)α,α -Diphenylprolinol, 98%

L09217 1g 5g
[112068-01-6]



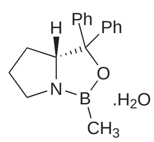
(R)-2-Methyl-CBS-oxazaborolidine, 1M soln. in toluene

L14582 1mL 5mL 25mL
[112022-83-0]



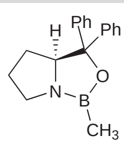
(R)-2-Methyl-CBS-oxazaborolidine monohydrate, 94%

L09230 250mg 1g



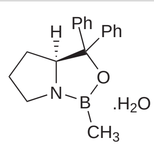
(S)-2-Methyl-CBS-oxazaborolidine, 1M soln. in toluene

L14583 1mL 5mL 25mL
[112022-81-8]



(S)-2-Methyl-CBS-oxazaborolidine monohydrate, 94%

L09219 250mg 1g



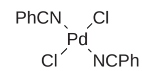
Coupling and hydroboration catalysts

Bis(acetonitrile)dichloropalladium(II)

10002 $(CH_3CN)_2PdCl_2$ 1g 5g
[14592-56-4]

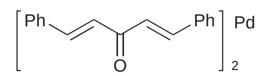
***trans*-Bis(benzonitrile)dichlorpalladium(II)**

10006 500mg 1g
[14220-64-5]



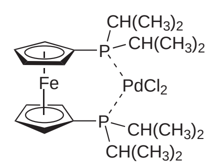
Bis(dibenzylideneacetone)palladium(0)

12764 250mg 1g 5g
[32005-36-0]



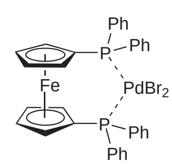
[1,1'-Bis(diisopropylphosphino)ferrocene] palladium(II) chloride

44978 1g 5g
[215788-65-1]



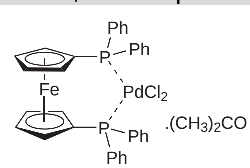
[1,1'-Bis(diphenylphosphino)ferrocene] palladium(II) bromide

44980 1g 5g
[124268-93-5]



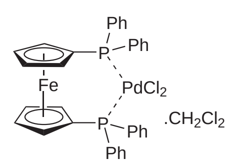
[1,1'-Bis(diphenylphosphino)ferrocene] palladium(II) chloride, 1:1 complex with acetone

44972 1g 5g
[851232-71-8]



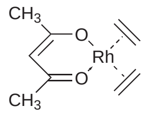
[1,1'-Bis(diphenylphosphino)ferrocene] palladium(II) chloride, 1:1 complex with dichloromethane

41225 1g 5g 25g
[72287-26-4]



Bis(ethylene)(2,4-pentanedionato)rhodium(I)

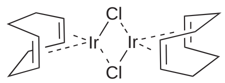
39288 [12082-47-2]



250mg
1g

Chloro(1,5-cyclooctadiene)iridium(I) dimer

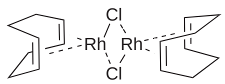
12749 [12112-67-3]



250mg
1g
5g

Chloro(1,5-cyclooctadiene)rhodium(I) dimer

10466 [12092-47-6]



250mg
1g

Chlorotris(triphenylphosphine)rhodium(I)

10468 [14694-95-2]

$(Ph_3P)_3RhCl$

250mg
1g
5g

Copper(II) acetate monohydrate

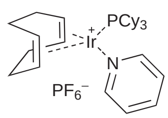
A16203 [6046-93-1]

$(CH_3COO)_2Cu\ .H_2O$

100g
500g
2.5kg

(1,5-Cyclooctadiene)(pyridine)(tricyclohexylphosphine)iridium(I) hexafluorophosphate, Crabtree's catalyst, 99%

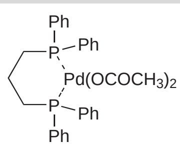
42057 [64536-78-3]



50mg
250mg
1g

Diacetato[1,3-bis(diphenylphosphino)propane] palladium(II)

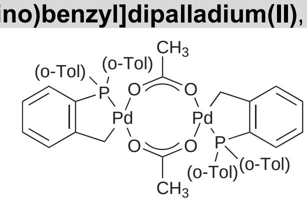
44970 [149796-59-8]



1g
5g

***trans*-Di-μ-acetatobis[2-(di-o-tolylphosphino)benzyl]dipalladium(II)**, 98%

L16948 [172418-32-5]



250mg
1g

Dibromobis(tri-o-tolylphosphine)palladium(II)

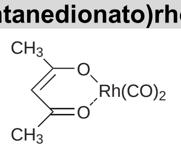
44979 [24554-43-6]

$[(o\text{-}Tol)_3P]_2PdBr_2$

1g
5g

Dicarbonyl(2,4-pentanedionato)rhodium(I), 99%

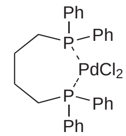
39295 [14874-82-9]



250mg
1g
5g

Dichlorobis(1,4-diphenylphosphinobutane) palladium(II)

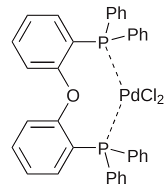
44971 [29964-62-3]



1g
5g

Dichlorobis(2-diphenylphosphinophenyl ether) palladium(II)

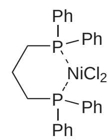
44977 [205319-06-8]



1g
5g

Dichlorobis(1,3-diphenylphosphinopropane) nickel(II)

30167 [15629-92-2]



2g
10g

Dichlorobis(tricyclohexylphoshine)palladium(II)

44844 [29934-17-6]

$[Cy_3P]_2PdCl_2$

1g

Dichlorobis(triphenylphosphine)nickel(II)

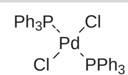
13930 [14220-64-5]

$(Ph_3P)_2NiCl_2$

5g
25g
100g

***trans*-Dichlorobis(triphenylphosphine) palladium(II)**

10491 [13965-03-2]



1g
5g
25g

Dichlorobis(tri-o-tolylphosphine)palladium(II)

44976 [40691-33-6]

$[(o\text{-}Tol)_3P]_2PdCl_2$

1g
5g

Palladium, 5% on carbon powder, dry

A12623

10g
50g

Palladium, 5% on carbon powder, standard, reduced, 50% water wet

38300

5g
25g
100g

Palladium, 5% on carbon powder, standard, unreduced, 50% water wet

38301

5g
25g
100g

Palladium, 10% on carbon powder, dry

A12012

2g
10g
50g

Palladium, 10% on carbon powder, standard, reduced, 50% water wet

38304

5g
25g
100g

Palladium, 5% on carbon powder, standard, unreduced, 50% water wet

38305

5g
25g
100g

Palladium(II) acetate, trimer

10516
[3375-31-3]

$[(CH_3COO)_2Pd]_3$

1g
2g
10g

Palladium(II) chloride

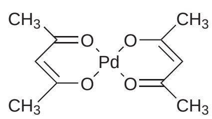
11034
[7647-10-1]

$PdCl_2$

1g
5g
25g

Palladium(II) 2,4-pentanedionate

10517
[14024-61-4]



1g
5g

Palladium tri-tert-butylphosphine bromide, dimer

44446
[185812-86-6]

$\{[(CH_3)_3C]_3PPdBr\}_2$

100mg
500mg
2g

Sodium tetrachloropalladate(II) hydrate

11886
[13820-53-6]

$Na_2PdCl_4 \cdot xH_2O$

1g
5g

Tetrakis(triphenylphosphine)palladium(0)

10548
[14221-01-3]

$(Ph_3P)_4Pd$

1g
5g
25g

Tetrakis(triphenylphosphine)platinum(0), 98%

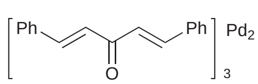
10549
[14221-02-4]

$(Ph_3P)_4Pt$

1g
5g

Tris(dibenzylideneacetone)dipalladium(0

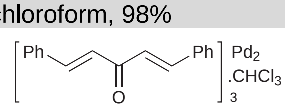
12760
[51364-51-3]



1g
5g

Tris(dibenzylideneacetone)dipalladium(0) complex with chloroform, 98%

L15980
[52522-40-4]

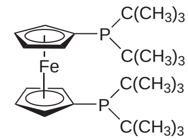


250mg
1g
5g

Phosphine ligands

1,1'-Bis(di-tert-butylphosphino)ferrocene, 98%

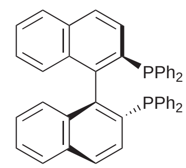
L19759
[84680-95-5]



500mg
2g

(R)-(+)-2,2'-Bis(diphenylphosphino)-1,1'-binaphthyl, 98%

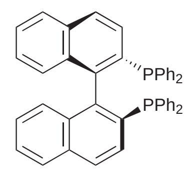
B23785
[76189-55-4]



100mg
250mg
1g

(S)-(-)-2,2'-Bis(diphenylphosphino)-1,1'-binaphthyl, 97%

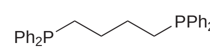
B23872
[76189-55-4]



100mg
250mg
1g

1,4-Bis(diphenylphosphino)butane, 98%

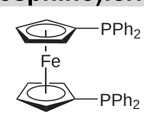
B21122
[100959-19-1]



1g
5g
25g

1,1'-Bis(diphenylphosphino)ferrocene, 97%

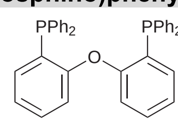
B21166
[12150-46-8]



1g
5g
25g

Bis[(2-diphenylphosphino)phenyl ether, 98%

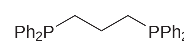
L18481
[166330-10-5]



1g
5g

1,3-Bis(diphenylphosphino)propane, 97%

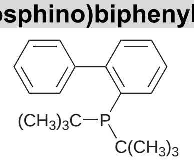
A12931
[6737-42-4]



5g
25g
100g

2-(Di-tert-butylphosphino)biphenyl, 99%

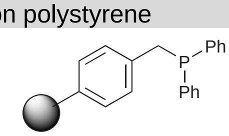
L19758
[224311-51-7]



500mg
2g
10g

Diphenylmethylphosphine, polymer-supported, 0.9-1.4 mmol/g on polystyrene

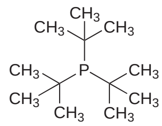
L19477



1g
5g
25g

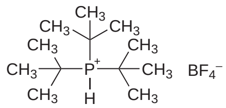
Tri-tert-butylphosphine, 96%

10178 1g, 5g
[13716-12-6]



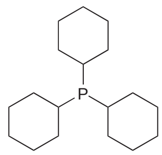
Tri-*tert*-butylphosphonium tetrafluoroborate, 98%

L19752 1g, 5g
[131274-22-1]



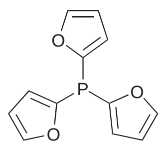
Tricyclohexylphosphine, 97%

30386 1g, 5g, 25g
[2622-14-2]



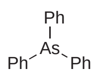
Tri(2-furyl)phosphine, 97%

L13329 1g, 5g
[5518-52-5]



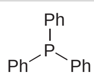
Triphenylarsine, 98%

L03616 5g, 25g
[603-32-7]



Triphenylphosphine, powder, 99%

L02502 50g, 250g, 1kg
[603-32-7]

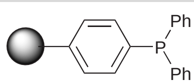


Triphenylphosphine, flake, 99%

A14089 250g, 1kg, 5kg
[603-32-7]

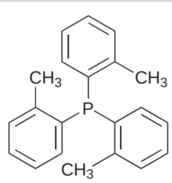
Triphenylphosphine, polymer-supported, 1.4-2.0 mmol/g on polystyrene

L19478 1g, 5g, 25g



Tri(*o*-tolyl)phosphine, 98+%

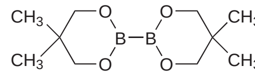
A12093 1g, 5g, 25g
[6163-58-2]



Boronylation reagents

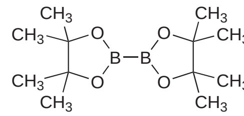
Bis(neopentyl glycolato)diboron, 97%

L18675 250mg, 1g, 5g
[201733-56-4]



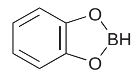
Bis(pinacolato)diboron, 99%

L16088 1g, 5g, 25g
[73183-34-3]



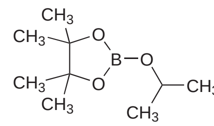
Catecholborane, 97%

L14998 5g, 25g
[274-07-7]



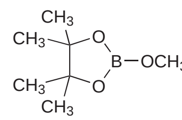
2-Isopropoxy-4,4,5,5-tetramethyl-1,3,2-dioxaborolane, 98%

L17278 1g, 5g, 25g
[61676-62-8]



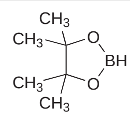
2-Methoxy-4,4,5,5-tetramethyl-1,3,2-dioxaborolane, 97%

L19056 5g, 25g
[1195-66-0]



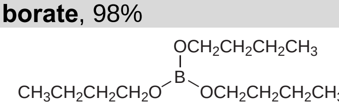
Pinacolborane, 97%

L17558 5g, 25g
[25015-63-8]



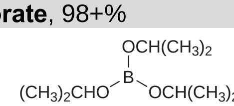
Tri-n-butyl borate, 98%

A19322 25mL, 100mL, 500mL
[688-74-4]



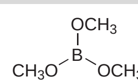
Triisopropyl borate, 98+%

A17592 100mL, 500mL, 2.5L
[5419-55-6]



Trimethyl borate, 99%

B20215 250mL, 1L
[121-43-7]



Boronic Acids

Properties and Applications

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