

A Publication of Strem Chemicals, Inc.

THE STREM CHEMIKER

VOL. XXVIII No. 1

June, 2015

Olefin Metathesis:



New Catalysts, New Solutions for Process Chemistry

by Tomasz K. Olszewski and Krzysztof Skowerski

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The Strem Chemiker
Vol. XXVIII No. 1

June, 2015

www.strem.com



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Biographical Sketches

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Olefin Metathesis: New Catalysts, New Solutions for Process Chemistry

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Introduction

Transition metal-catalyzed olefin metathesis is a powerful set of transformations that has received significant attention in advanced organic synthesis for the formation of C-C double bonds which it enables.¹ The success of these reactions is associated with the development of ruthenium-based catalysts which are stable in air and moisture and which additionally display excellent functional group tolerance. **G-I** introduced by Grubbs in 1996 was a key milestone in this field.² Another breakthrough was made by Hoveyda who introduced complex **H-I**, with a bidentate benzyldiene ligand.³ Further developments resulted in the discovery of more active and robust "second generation" catalysts bearing an *N*-heterocyclic carbene (NHC) ligand (**G-II**,⁴ **H-II**⁵). These discoveries provided an excellent opportunity for the "fine-tuning" of the catalysts' properties which makes them more selective and/or better suited for large scale processes. Early examples of relatively simple catalyst modifications which offer significant benefits were described by Blechert who presented sterically activated **B-II**⁶ and Grela who introduced electronically activated **nitro-Grela**.⁷ Both, **B-II** and **nitro-Grela** initiate dramatically faster than the parent **H-II**, and importantly, **nitro-Grela** maintains high stability in solid state as well as in solution which is a key characteristic for **H-II**.

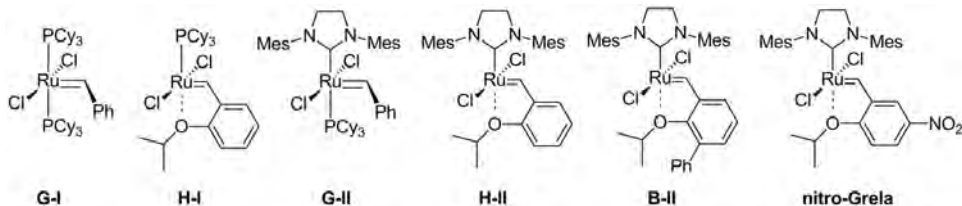


Figure 1. Classical olefin metathesis catalysts (Mes = 2,4,6-trimethylphenyl, Cy = cyclohexyl)

Apart from the industrial application of ring-opening metathesis polymerization (ROMP) and acyclic diene metathesis polymerization (ADMET),⁸ olefin metathesis is used for the preparation of well-defined organic compounds either by cross metathesis (CM) or by ring-closing metathesis (RCM). The latter is one of the most frequently used methods of C-C-bond formation in the synthesis of carbocyclic and heterocyclic compounds.⁹ Also, cyclic amino acids,¹⁰ peptides and peptidomimetics,¹¹ polycyclic alkaloids,¹² as well as carbohydrates¹³ have been synthesized via olefin metathesis. In particular, medium sized rings and macrocyclic compounds¹⁴ can be more easily prepared by RCM than by classical methods.^{15,16} The importance of olefin metathesis was recognized in 2005 with the award of the Nobel Prize in Chemistry to Yves Chauvin, Richard R. Schrock, and Robert H. Grubbs.¹⁷

nitro-Grela in the synthesis of complex molecules

Due to its excellent catalytic activity, **nitro-Grela** has found numerous applications in the total syntheses of natural and biologically active compounds, such as (–)-securinine,^{18a} a precursor of hexacyclinic acid,^{18b} (+)-ricciocarpin A,^{18c} the viridifungin A derivative,^{18d} largazole,^{18e} FR901464,^{18f} relacatib a cathepsin K inhibitor,^{18g} and recently in an elegant total synthesis of ripostatin B, a 14-membered macrolactone and eubacterial RNA polymerase inhibitor (Figure 2).^{18h}

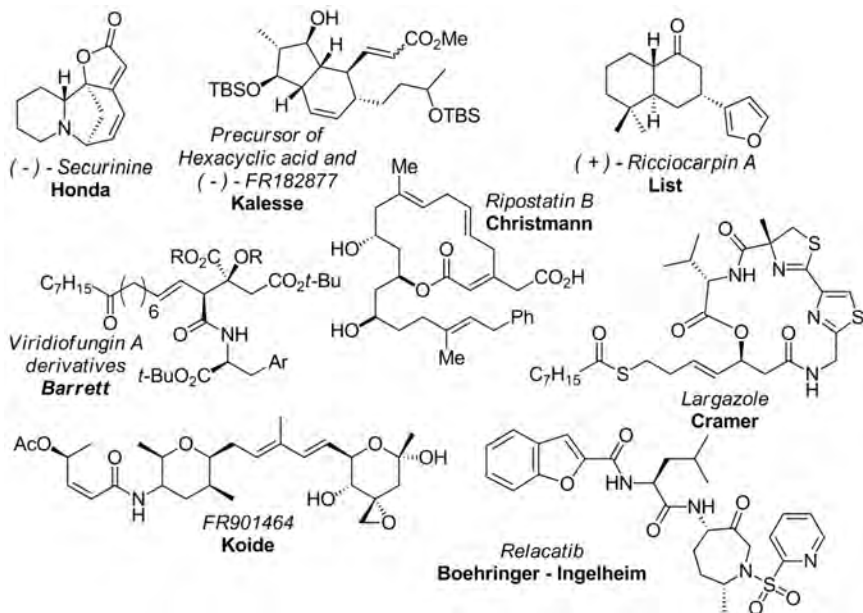
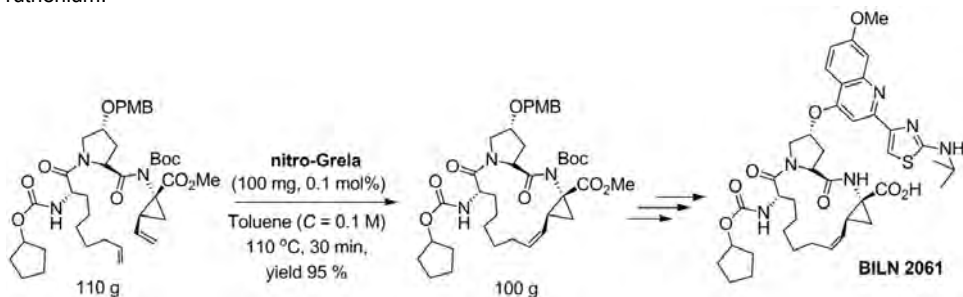


Figure 2. Selected applications of **nitro-Grela** in synthesis of biologically relevant compounds.

The macrocyclization which led to a precursor of the HCV inhibitor **BILN 2061**, accomplished by scientists from pharmaceutical company Boehringer Ingelheim (BI), was the very first example of the application of metathesis in the synthesis of an API. The catalyst **H-I** was used in the first generation process which resulted in total, in the synthesis of 400 kg of macrocyclic intermediate.^{19a} Several problematic issues were raised during the scale-up of macrocyclization, such as: a) difficult removal of ethylene which led to decreased efficiency of **H-I** (up to 5.3 mol% of catalyst was required vs. 3 mol% at laboratory scale), b) long reaction times (up to 12h), c) formation of 10-15% of isomerization by-product due to traces of morpholine in toluene, and, d) high levels of difficult-to-remove residual ruthenium (up to 1000 ppm). Following this scale-up effort, an extremely extensive research project led to an in-depth understanding of this described macrocyclization reaction and the development of a second generation process.^{19b-d} The crucial improvement lay in the introduction of a Boc protecting group into amide nitrogen which resulted in dramatic positive changes in the kinetics and thermodynamics of the macrocyclization. The new diene (Scheme 1), in combination with an active and efficient **nitro-Grela** initiator had the following results: a) it allowed the reaction to run at 0.1M, b) it permitted a reduction of catalyst loading to 0.1 mol% and, c) it reduced the reaction time to 30 mins. The product was isolated with 95% of yield and contained an easily removable trace of residual ruthenium.



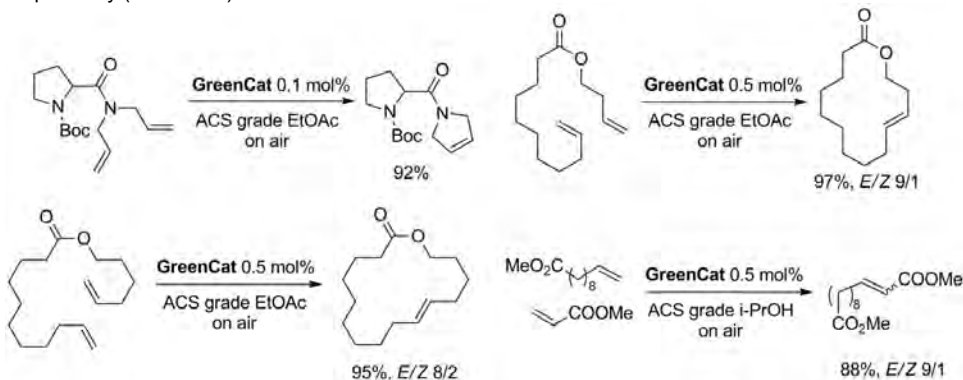
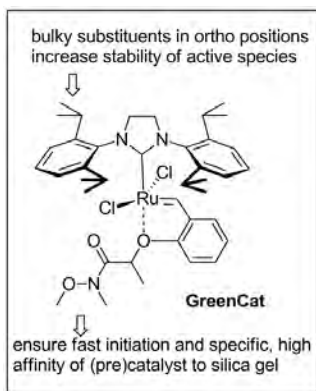
Scheme 1. Synthesis of **BILN 2061** (PMB = *p*-Methoxybenzyl).

The early stage process utilizing the first generation approach for the production of the **BILN2016** macrocyclic precursor illustrates the major problems related to the application of ring-closing metathesis in the pharmaceutical industry such as: 1) high dilution required to minimize intermolecular metathesis reactions, 2) the necessity for high catalyst loading due to its sensitivity towards traces of impurities, 3) high residual ruthenium content in the product of the metathesis reaction. After extensive optimization leading to the second generation process, all of these issues were elegantly circumvented by scientists from Boehringer Ingelheim. However, we are convinced that with the utilization of catalysts which are even more process-oriented than nitro-Grela, at least some of the above mentioned problems may be completely eliminated.

The following describes a series of fine-tuned catalysts with properties highly desired for use during both laboratory scale development of APIs, as well as process development.

GreenCat – Excellent compatibility with low-grade “green” solvents, easy catalyst recovery/reuse, low residual ruthenium

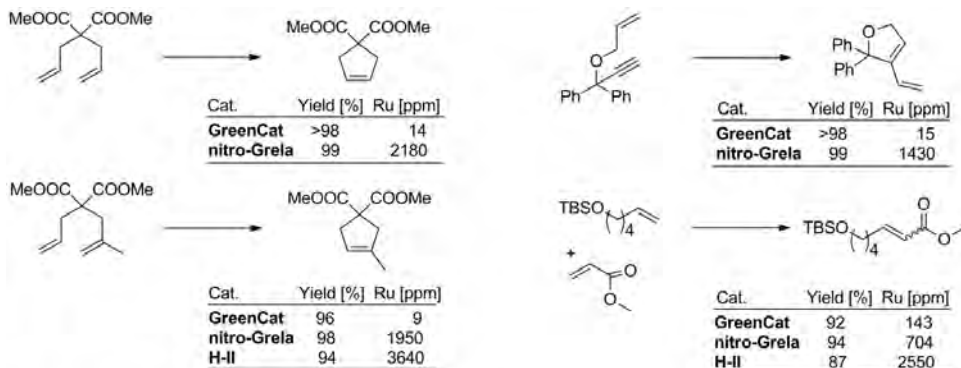
Olefin metathesis is usually regarded as a reaction that requires an inert atmosphere and very pure, anhydrous solvents. Moreover, in most cases, environmentally detrimental aromatic or chlorinated solvents have been required.²⁰ For large-scale synthesis, the implications of reaction solvent choices must be considered carefully; among other issues, the costs of purchase, as well as purification and drying of the solvents are considerable. Therefore, the usage of ACS grade solvents without degassing and drying can be beneficial from both an economic and practical point of view, providing that the catalyst can be sufficiently effective in such conditions. Along these lines, scientists from Apeiron Synthesis have focused their attention on targeted ligand modifications which led to the development of **GreenCat** which demonstrates a fast initiation rate together with excellent stability in solid state and in solution, as well as exceptional effectiveness under harsh conditions. As presented below, **GreenCat** promotes challenging RCM and CM while allowing reactions to be performed under air, as well as in ACS grade ethyl acetate and *i*-PrOH respectively (Scheme 2).²¹



Scheme 2. Catalytic activity of **GreenCat** in air and in ACS grade “green” solvents.²¹

At laboratory scale, where utilization of DCM is still the day-to-day practice, **GreenCat** offers additional benefits due to an extraordinarily high affinity of this catalyst to silica gel when DCM is used as an eluent for flash chromatography. This characteristic can be utilized for the easy creation of small molecule libraries with significantly reduced residual ruthenium. As can be seen in Scheme 3, the residual ruthenium in products obtained utilizing **GreenCat** is from 5 to 400 times lower than in the case of products synthesized with **H-II** or **nitro-Grela**. Moreover, it is quite common that at the early stage of development, organic chemists are more interested in a fast and high yield accomplishment of the metathesis step rather than in searching for optimal catalyst loading. This is

reflected in typical loadings of 5 mol% or higher which can lead not only to problems with residual ruthenium removal, but also leads to the fast consumption of relatively expensive ruthenium complex. **GreenCat** solves this issue since it can be applied at high loadings while still providing product with significantly reduced residual ruthenium (<200 ppm vs. >2000 ppm with classical catalysts). Conveniently, the non-activated or reformed (by the so called “boomerang effect”) portion of **GreenCat** ppm with classical catalysts).



Conditions: **Catalyst** 1 mol%, DCM, 0.05 M, 40 °C

Scheme 3. Removal of residual ruthenium by flash chromatography using DCM as an eluent.

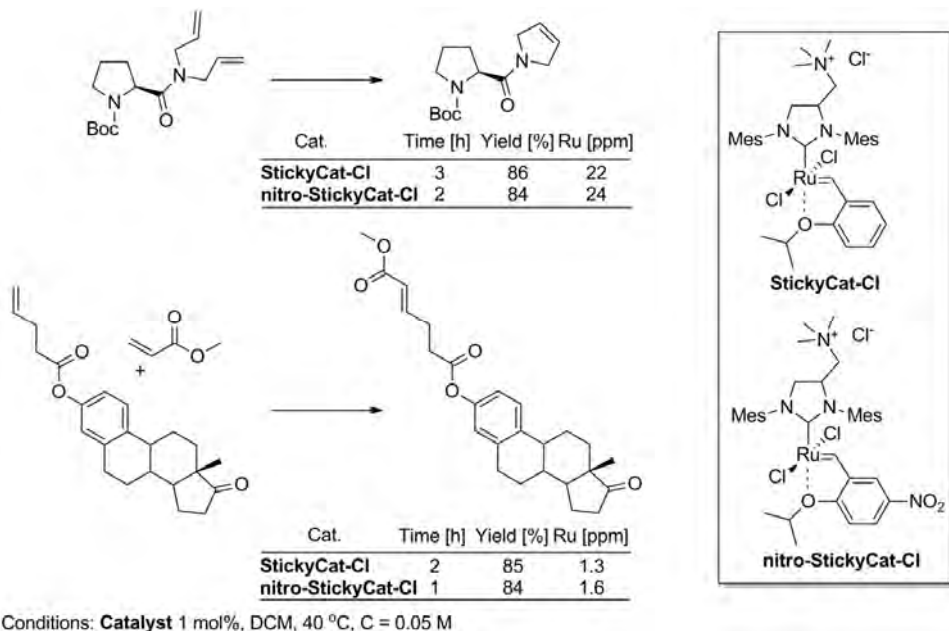
Conveniently, the non-activated or reformed (by the so can be recovered from the silica gel – by changing the eluent from DCM to EtOAc – and subsequently reused. Using this approach and 61 mg (2 mol%) of **GreenCat**, five metathesis products were obtained with very good yields and a GC purity of >98% and then after the last reaction, 36 mg of catalyst was recovered.

Ammonium-tagged catalysts – Great processing opportunities thanks to the one polar group

Removal of residual ruthenium from the reaction product after metathesis – general description.

Residual ruthenium in the products of metathesis is a well known and difficult to solve issue. Several problems are related to the presence of ruthenium in finished products such as: a) legal – in the case of API's (e.g. for orally administered drugs, ruthenium content must not exceed 10ppm)²² and materials that have direct contact with the human body (e.g. polymers for biomedical applications);²³ b) processing – traces of ruthenium can cause side reactions during work-up procedures or subsequent synthetic steps;²⁴ c) reduced product parameters (e.g. polymers for application in the electronics industry); and, d) aesthetic – unwanted colorization of the product. Various techniques can be used to purge ruthenium from the post-reaction mixture, but these methods are often time- and/or energy-consuming, show limited effectiveness and suffer from lack of generality.²⁵ An alternative approach is based on the application of modified catalysts that can be easily removed upon completion of the reaction. The tag, which gives specific properties to the catalyst, should be placed in non-labile ligand in order to ensure efficient removal of ruthenium traces. The NHC-backbone, chosen by Apeiron, appears to be the most beneficial site of modification. It should be mentioned that several tagged/heterogeneous catalysts have been reported so far, however, probably due to their complicated synthesis, none of them is commercially available.²⁶ During the development of our ammonium-tagged catalysts, we paid special attention to the scalability of their synthesis and thus each catalyst described herein is now available in kg quantities. *Removal of residual ruthenium by extraction with water.*

Ammonium-tagged catalysts bearing chloride counter-ion(s), represented by our core catalyst – **StickyCat-Cl**, are soluble in both chlorinated organic solvents as well as in water. This property provides an opportunity for the removal of residual ruthenium by extraction of the reaction mixture with water.²⁷ Tested reactions were intentionally run with high catalyst loadings (1 mol%) to examine the efficiency of residual ruthenium removal. For the majority of substrates, five extractions of dichloromethane phase with water reduced ruthenium levels below 10 ppm (Scheme 4). We also demonstrated that the addition of a small amount of silica gel, to ruthenium-containing water fractions led to the deposition of ruthenium on silica. This created an opportunity for the reuse of the water and

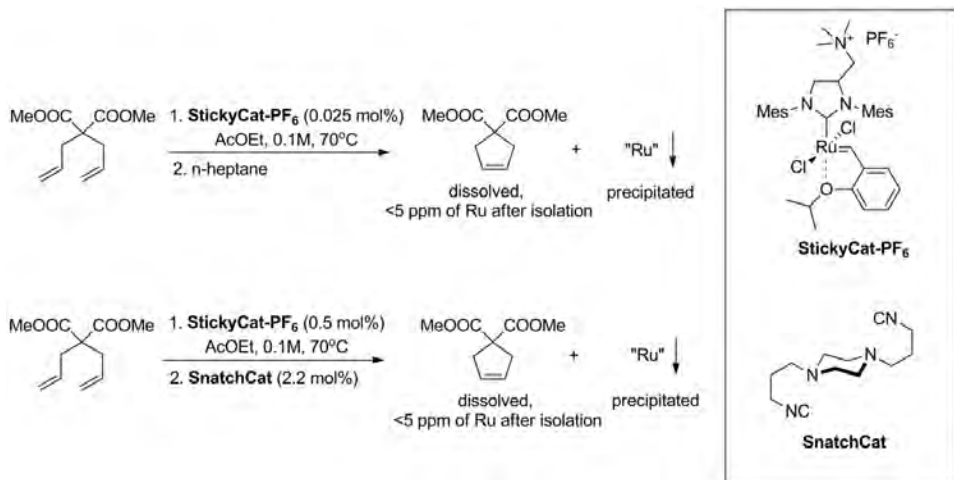


Scheme 4. Removal of residual ruthenium by extraction with water.

the easy disposal of a small amount of silica gel contaminated with ruthenium. Placement of an ammonium tag in NHC-backbone also presents the possibility for further fine-tuning of the catalysts' properties. For example, introduction of a nitro group into benzylidene ligand creates a water-soluble and easily removable analog of the well-established nitro-Grela catalyst.

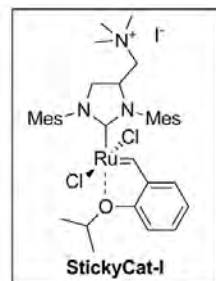
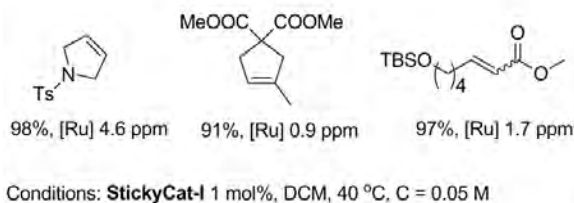
Removal of residual ruthenium by precipitation.

At production scale, the application of chlorinated organic solvents is highly undesirable. Searching for more environmentally and user-friendly conditions we turned our attention to ethyl acetate. In this solvent however, the **StickyCat-Cl** shows very low solubility and limited catalytic activity. Advantageously, the exchange of a chloride counter-ion with PF₆ creates **StickyCat-PF₆**, which displays solubility in EtOAc which is sufficient to perform a catalytic reaction. Moreover, at low catalyst loadings, the ruthenium-containing species can be precipitated by the addition of a nonpolar solvent (e.g. heptane) which led to the isolation of a virtually ruthenium-free product after simple filtration through a Schott funnel (Scheme 5). Similar precipitation effects without the addition of non-polar solvents can be obtained due to the reaction of our proprietary metal scavenger **SnatchCat** with ruthenium species.²⁷ Importantly, this approach is not limited to reactions with low catalyst loadings.



Removal of residual ruthenium by silica gel work-up.

A silica gel work-up can be applied for the removal of residual ruthenium after application of any ammonium tagged catalyst in any solvent. Filtration of the reaction mixture through a short pad of silica gel or its stirring with silica gel and subsequent filtration through a Schott funnel provides products with dramatically reduced ruthenium levels (Scheme 6).²⁸

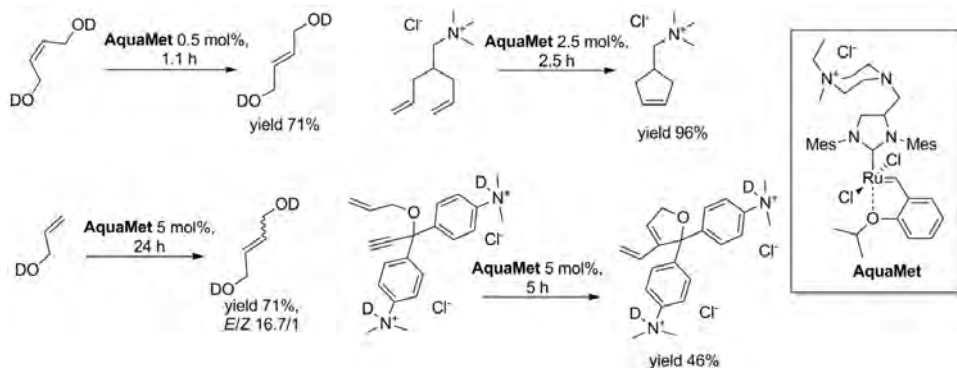


Scheme 6. Removal of residual ruthenium by filtration through a plug of silica gel.

Heterogeneous catalysts – ruthenium-free products and beyond.

Depending on the nature of the substrate/product and expectations for the process parameters it can be beneficial to use heterogeneous instead of homogeneous catalysts. Naturally, application of a heterogeneous catalyst will provide a ruthenium-free product. Moreover, by making the proper selection of support and/or parameters for a continuous-flow process, the selectivity of the reaction can be greatly improved.²⁹ Ammonium tagged catalysts can be easily immobilized on siliceous supports as we demonstrated by the synthesis of **AquaMet/SBA-15**.³⁰ This catalyst proves to be especially useful in transformations which proceed without evolution of ethylene – TON of 16000 was obtained in RCM of β (-)-citronellene. Worth highlighting is the very low residual ruthenium content in the metathesis products (typically ≤ 7.5 ppm) after simple separation of the catalyst by filtration on a Schott funnel.²⁹ Very recently a heterogeneous catalyst with dramatically improved stability and efficiency in RCM and CM of terminal dienes has been developed in our laboratory and will be reported and commercially available soon.

Water is the universal solvent in nature in that almost all biochemical reactions in living cells proceed in aqueous media. According to this universal condition, pharmaceutically and biologically relevant molecules are usually polar and only soluble in water or aqueous media. To this end, olefin metathesis in water, as an atom-efficient approach with high functional group tolerance and mild reaction conditions, represents a very interesting tool for the production of polar pharmaceutically important compounds.³¹



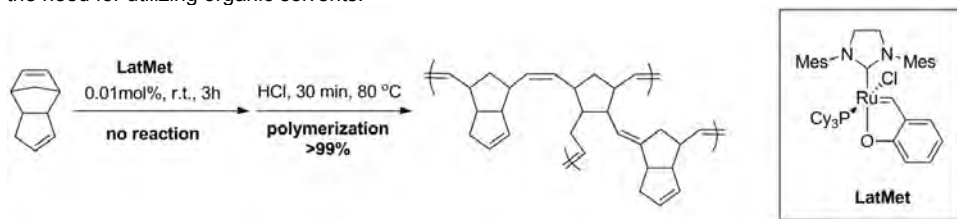
Scheme 7. Catalytic activity of **AquaMet** in neat water.

The **AquaMet** catalyst was found to be active in isomerization, CM, RCM, and enyn metathesis in neat water.³² Recently the RCM leading to a 5-membered ring (see Scheme 7) has been accomplished with 90% NMR yield using, as is typical, a non-degassed solvent in air and only 0.75 mol% of **AquaMet**. This result suggests that the great potential of olefin metathesis in water is still yet to be explored.

LatMet and its application in olefin metathesis polymerization

Polydicyclopentadiene (pDCPD) is a resin-like polymer used for the production of finished products in reaction-injection molding (RIM) processes and related techniques. Extremely high reactivity of DCPD creates special requirements for catalysts. Typical Grubbs and Hoveyda-Grubbs catalysts are too reactive and do not offer enough time to create formulation. The so-called "latent" catalysts which require chemical and/or thermal activation are considered to be the best option for polymerization of DCPD.

Due to the presence of a covalent Ru-O bond, where oxygen is also connected with dissociating benzylidene ligand, the **LatMet** catalyst does not cause polymerization of DCPD for a period of several hours at temperatures below 40°C. The addition of HCl and an increase in temperature are required for activation of **LatMet** (Scheme 8). Conveniently, after the addition of an acidic activator, the **LatMet** does not initiate immediately, but leaves enough time to further handle the reaction mixture.³³ An additional advantage of **LatMet** is its very good solubility in neat DCPD which eliminates the need for utilizing organic solvents.



Scheme 8. Application of **LatMet** in polymerization of dicyclopentadiene in neat conditions.

Economics of olefin metathesis

The contribution of catalyst costs to the overall production expenses for the finished product can have a decisive impact on the economic feasibility of many projects. This is especially true for non-pharmaceutical applications where margins are often significantly lower. The multistep synthesis required for most catalysts, the price of ruthenium and the patent costs contribute to relatively high prices for most olefin metathesis catalysts. This problem can in most cases be circumvented by the reduction of catalyst loading which is usually a question of: a) proper selection of substrate/catalyst pair, b) substrate and solvent purity, and, c) reaction conditions. Using our catalysts we typically obtain: a) small and medium rings via RCM with catalyst loadings of 0.001-0.025 mol%, b) macrocyclic lactones/ketones having low effective molarity using <0.1 mol% of catalyst, c) products of challenging CM (e.g. with electron deficient partners) in the presence of <0.025 mol% of catalyst, and, d) products of self-metathesis (internal and terminal alkenes) and ROMP with the application of <0.005 mol% of catalyst.

Conclusions

Olefin metathesis is an already mature technology ready to be widely commercialized, but there remain challenges. However, to address some of these challenges, the catalysts developed by Apeiron are making the development of metathesis-based processes feasible from the very beginning thanks to their excellent compatibility with a wide range of solvents, high efficiency even in the presence of traces of impurities, as well as easy, fast and efficient removal of residual ruthenium. Good water solubility and high activity in mild conditions opens new possibilities for the transformation of highly polar API's, but also allows powerful tandem metathesis/biochemical transformations. Efficient heterogeneous catalysts provide excellent opportunities for the design of continuous flow processes and present exceptionally easy synthesis of products with very low amounts of residual ruthenium. The low loadings achievable with our robust catalysts opens possibilities for the application of olefin metathesis in a broad range of sectors in the chemical industry.

Acknowledgments

We thank Mr. Eric Grunebaum and Dr. Grażyna Szymańska for careful proofreading of this manuscript.

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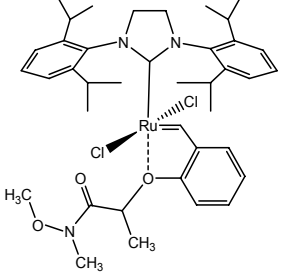
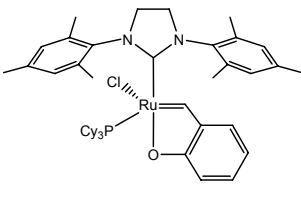
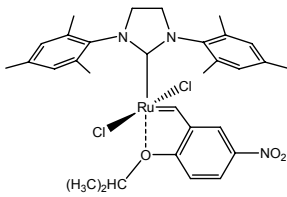
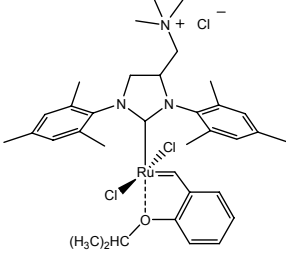
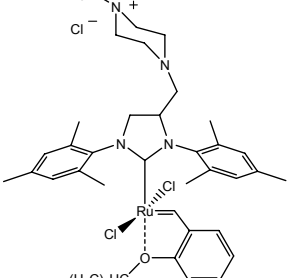
APEIRON RUTHENIUM METATHESIS CATALYST KIT

96-0400

Apeiron Ruthenium Metathesis Catalyst Kit

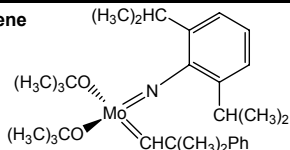
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Contains the following:

		
44-0750 100mg	44-0753 100mg	44-0758 100mg
		Components available for individual sale.
44-0765 100mg	44-0768 100mg	
44-0750	[1,3-Bis(2,6-di- <i>i</i> -propylphenyl)imidazolidin-2-ylidene][2-[[1-(methoxy(methyl)amino)-1-oxopropan-2-yl]oxy]benzylidene]ruthenium(VI) dichloride GreenCat [1448663-06-6]	See page 15
44-0753	[1,3-Bis(2,4,6-trimethylphenyl)imidazolidin-2-ylidene][(tricyclohexylphosphine)(2-oxobenzylidene)ruthenium(VI) chloride LatMet [1407229-58-6]	See page 20
44-0758	[1,3-Bis(2,4,6-trimethylphenyl)imidazolidin-2-ylidene]-(2- <i>i</i> -propoxy-5-nitrobenzylidene) ruthenium(VI) dichloride nitro-Grela [502964-52-5]	See page 19
44-0765	[1,3-Bis(2,4,6-trimethylphenyl)-4-[(trimethylammonio)methyl]imidazolidin-2-ylidene]-(2- <i>i</i> -propoxybenzylidene)dichlororuthenium(VI) chloride StickyCat Cl [1452227-72-3]	See page 20
44-0768	[1,3-Bis(2,4,6-trimethylphenyl)-4-[(4-ethyl-4-methylpiperazin-1-ium-1-yl)methyl]imidazolidin-2-ylidene]-(2- <i>i</i> -propoxybenzylidene)dichlororuthenium(VI) chloride AquaMet [1414707-08-6]	See page 17

MOLYBDENUM (Compounds)

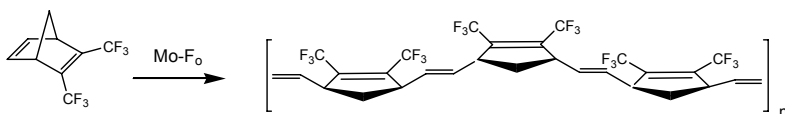
42-1200 **2,6-Diisopropylphenyl imidoneophylidene**
 amp **molybdenum(VI) bis(t-butoxide)**
 [126949-65-3]
 $\text{Mo}(\text{C}_{10}\text{H}_{12})(\text{C}_{12}\text{H}_{17}\text{N})(\text{OC}_4\text{H}_9)_2$;
 FW: 549.65;
 yellow to orange powdr.
air sensitive, moisture sensitive,
(store cold)



100mg
 500mg
 2g

Technical Note:

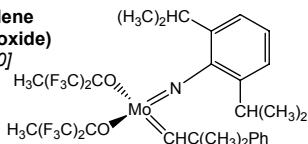
1. The "ROMP" catalyst (Mo-F_6) is a relatively mild initiator for the living ROMP of functionalized norbornenes and norbornadienes that do not contain active protons.

**References:**

1. *Ring-Opening Polymerization* (D.J. Brunelle, Ed.), **1993**, 129.
2. *J. Am. Chem. Soc.*, **1990**, 112, 8378.

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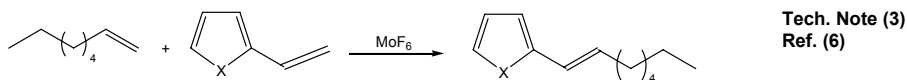
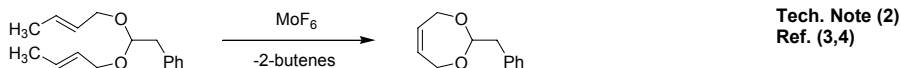
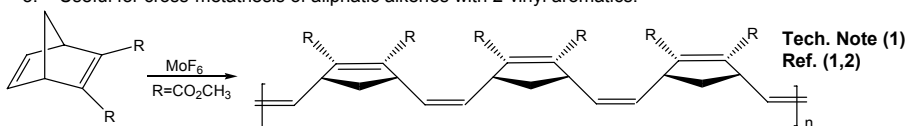
42-1205 **2,6-Diisopropylphenylimidoneophylidene**
 amp **molybdenum(VI) bis(hexafluoro-t-butoxide)**
SCHROCK'S CATALYST [139220-25-0]
 $\text{Mo}(\text{C}_{10}\text{H}_{12})(\text{C}_{12}\text{H}_{17}\text{N})(\text{OC}(\text{CH}_3)(\text{CF}_3)_2)_2$;
 FW: 765.53; yellow to orange powdr.
air sensitive, moisture sensitive,
(store cold)



100mg
 500mg
 2g

Technical Notes:

1. Unlike $\text{Mo}(\text{C}_{10}\text{H}_{12})(\text{C}_{12}\text{H}_{17}\text{N})(\text{OC}_4\text{H}_9)_2$, the bis(hexafluoro-t-butoxide) (MoF_6) derivative will metathesize many ordinary olefins, especially terminal olefins, and will ROMP many norbornene or substituted norbornadiene monomers to give all cis, and often isotactic, polymers.
2. Useful for the "ring-closing" of dienes or the coupling of terminal olefins.
3. Useful for cross-metathesis of aliphatic alkenes with 2-vinyl aromatics.



$\text{X} = \text{CH}=\text{CH}, \text{S}, \text{O}$

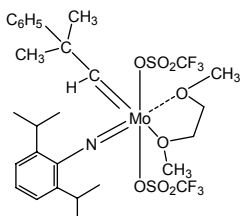
References:

1. *J. Am. Chem. Soc.*, **1994**, 116, 3414.
2. *J. Am. Chem. Soc.*, **1993**, 115, 4413.
3. *J. Am. Chem. Soc.*, **1992**, 114, 5426.
4. *J. Am. Chem. Soc.*, **1992**, 114, 7324.
5. *Tetrahedron*, **1998**, 54, 4413. (review article)
6. *J. Mol. Catal. Chem.*, **2002**, 190, 45.

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MOLYBDENUM (Compounds)

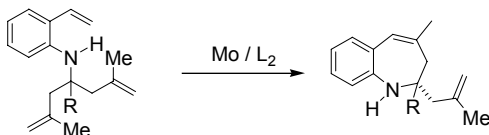
42-1210 **2,6-Diisopropylphenylimido neophylidene molybdenum(VI) bis(trifluoromethanesulfonate)dimethoxyethane adduct**
[126949-63-1]
 $\text{Mo}(\text{C}_{10}\text{H}_{12})(\text{C}_{12}\text{H}_{17}\text{N})(\text{OSO}_2\text{CF}_3)_2(\text{C}_4\text{H}_{10}\text{O}_2)$;
 FW: 791.68; yellow to orange powdr.
air sensitive, moisture sensitive, (store cold)



100mg
500mg

Technical Notes:

- Starting material for the preparation of other "ROMP" catalysts. Catalysts can be prepared (even *in situ*) by adding the appropriate alkoxide, including enantiomerically pure alkoxide ligands such as 3,3'-disubstituted binaphtholates or tartrates.
- Asymmetric ring closing metathesis of amines.

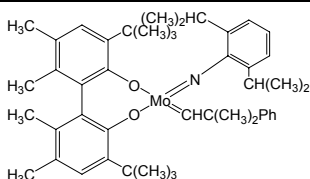


Tech. Note (2)
Ref. (3)

References:

- J. Am. Chem. Soc.*, **1993**, 115, 4413.
- Angew. Chem. Int. Ed.*, **2001**, 40, 1452.
- Org. Lett.*, **2003**, 5, 4899.

42-1212 **2,6-Diisopropylphenyl-imidoneophylidene [racemic-BIPHEN] molybdenum(VI), min. 97% rac-SCHROCK-HOVEYDA CATALYST**
[300344-02-9]
 $\text{Mo}(\text{C}_{10}\text{H}_{12})(\text{C}_{12}\text{H}_{17}\text{N})(\text{C}_{24}\text{H}_{32}\text{O}_2)$;
 FW: 755.93; red xtl.
air sensitive, moisture sensitive, (store cold)



100mg
500mg

BIPHEN = 5,5',6,6'-Tetramethyl-3,3'-di-*t*-butyl-1,1'-biphenyl-2,2'-diol

Technical Note:

- A ring-closing metathesis catalyst.

Visit strem.com for additional technical notes.

42-1213 **2,6-Diisopropylphenylimidoneophylidene[(R)-(+)-BIPHEN] molybdenum(VI), min. 97% (R) SCHROCK-HOVEYDA CATALYST**
[329735-77-5]
 $\text{Mo}(\text{C}_{10}\text{H}_{12})(\text{C}_{12}\text{H}_{17}\text{N})(\text{C}_{24}\text{H}_{32}\text{O}_2)$; FW: 755.93; red xtl.
air sensitive, moisture sensitive, (store cold)

100mg

Technical Note:

- See 42-1214 (page 14).

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MOLYBDENUM (Compounds)

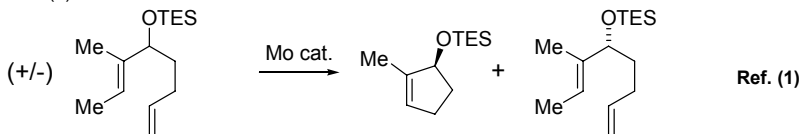
42-1214 **2,6-Diisopropylphenylimidoneophylidene[(S)-(-)-BIPHEN]**
 amp molybdenum(VI), min. 97% (S) SCHROCK-HOVEYDA CATALYST
 [205815-80-1]
 Mo(C₁₀H₁₂)(C₁₂H₁₇N)(C₂₄H₃₂O₂); FW: 755.93; red xtl.
air sensitive, moisture sensitive, (store cold)

100mg

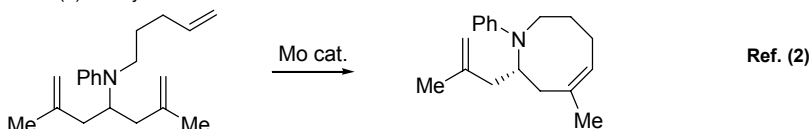
Technical Note:

- The new Schrock-Hoveyda, chiral molybdenum catalyst can effect various modes of enantioselective olefin metathesis with excellent selectivity.

(a) Kinetic resolution.



(b) Desymmetrization of tri- or tetraenes.



(c) Asymmetric Ring-Opening metathesis/Ring-Closing metathesis.



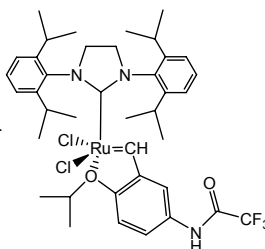
References:

- J. Am. Chem. Soc.*, **1998**, 120, 4041.
- J. Am. Chem. Soc.*, **2005**, 127, 8526.
- Chem. Eur. J.*, **2001**, 7, 945. (review)
- Angew. Chem. Int. Ed.*, **2003**, 42, 4592. (review)
- J. Am. Chem. Soc.*, **1999**, 121, 11603.
- J. Am. Chem. Soc.*, **2006**, 128, 5153.
- Angew. Chem. Int. Ed.*, **2007**, 46, 4534.

Visit strem.com for additional technical notes.**RUTHENIUM (Compounds)**

96-0400 **Apeiron Ruthenium Metathesis Catalyst Kit**
NEW→ See (page 11).

44-0055 **[1,3-Bis(2,6-di-i-propylphenyl)-4,5-dihydroimidazol-2-ylidene]-[2-i-propoxy-5-(trifluoroacetamido)phenyl]methylene-ruthenium(II) dichloride M71-S1Pr**
 [1212008-99-5]
 C₃₉H₅₀Cl₂F₃N₃O₂Ru; FW: 821.80; green powdr.
 Note: Sold under license from Omega Cat System for research purposes only
 WO 2008/065187, PCT/EP2008/054901, Fr n°08/05403.

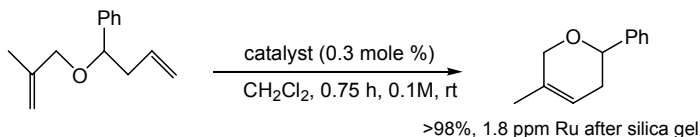
100mg
500mg

Technical Note:

- Enhanced activity ruthenium "boomerang" pre-catalyst used in the olefin metathesis, enyne metathesis, and cross metathesis reactions, that can be recycled, and leaves no reduced ruthenium in the product after silica gel chromatography.

RUTHENIUM (Compounds)

44-0055 [1,3-Bis(2,6-di-*i*-propylphenyl)-4,5-dihydroimidazol-2-ylidene]-[2-*i*-propoxy-5-(trifluoroacetamido)phenyl]methyleneruthenium(II) dichloride **M71-S1Pr**
[1212008-99-5]



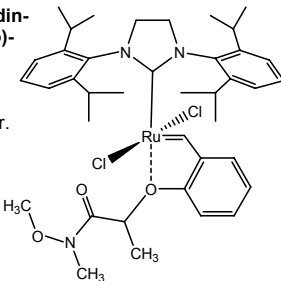
Tech. Note (1)
Ref. (1,2)

References:

- Eur. J. Org. Chem.*, **2009**, 4254.
- J. Org. Chem.*, **2008**, 73, 4225.

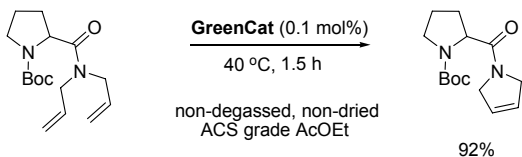
44-0750 [1,3-Bis(2,6-di-*i*-propylphenyl)imidazolidin-2-ylidene][2-[[1-(methoxy(methyl)amino)-1-oxopropan-2-yl]oxy]benzylidene]ruthenium(VI) dichloride **GreenCat**
[1448663-06-6]
C₃₉H₆₃Cl₂N₃O₃Ru; FW: 783.33; green powdr.
Note: Sold in collaboration with Apeiron Synthesis, Inc. Apeiron Ruthenium Metathesis Kit Component. See (page 11).

100mg
500mg

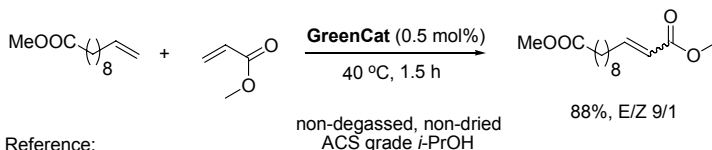


Technical Note:

- Efficient, durable and reusable olefin metathesis catalyst with a high affinity to silica gel.



Tech. Note (1)
Ref. (1)



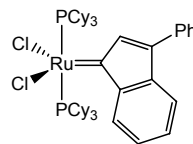
Tech. Note (1)
Ref. (1)

Reference:

- Tetrahedron*, **2013**, 69, 7408.

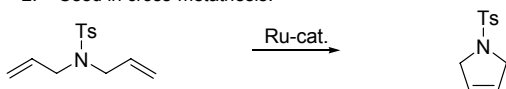
44-0063 Bis(tricyclohexylphosphine)-3-phenyl-1H-inden-1-ylideneruthenium(II) dichloride [250220-36-1]
RuCl₂(C₁₅H₁₀)[P(C₆H₁₁)₃]₂; FW: 923.07; brown powdr.

1g
5g

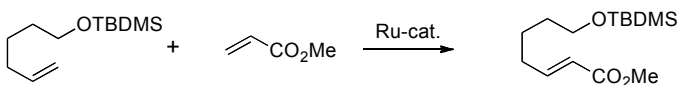


Technical Notes:

- Highly active, air-stable catalyst used for the ring closing metathesis of dienes.
- Used in cross-metathesis.



Tech. Note (1)
Ref. (1)



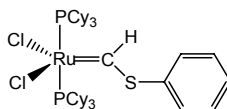
Tech. Note (2)
Ref. (2)

References:

- Angew. Chem. Int. Ed.*, **2000**, 112, 3012. (review article)
- Adv. Synth. Catal.*, **2008**, 350, 2959.

RUTHENIUM (Compounds)

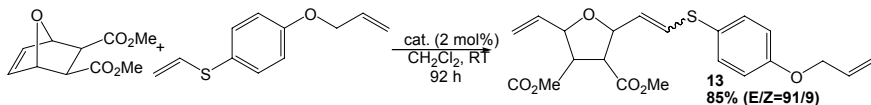
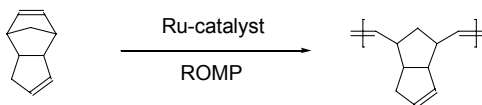
44-0073 **Bis(tricyclohexylphosphine)[(phenylthio)methylene]ruthenium(II) dichloride, min. 97%** [219770-99-7]
 $\text{RuCl}_2(\text{CHSC}_6\text{H}_5)[\text{P}(\text{C}_6\text{H}_{11})_3]_2$; FW: 855.02;
 purple powdr.
 Note: Sold in collaboration with BASF for research purposes only.
 Patents US 6,407,190 and EP 993,465.



1g
5g

Technical Notes:

1. Metathesis catalyst, stable in air and can be used in aqueous media.
2. Catalyst of choice for the ring-opening metathesis polymerization of cycloolefins.
3. Catalyst concentration 2-3 times lower than comparable phenyl and vinyl substituted ruthenium carbenes.
4. Excellent initiator for solvent-free polymerization and control of initiation rates and gelation times.
5. Highly selective catalyst for the ring opening/cross-metathesis of norbornene derivatives.

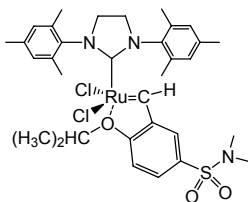


Tech. Note (5)
Ref. (3)

References:

1. *J. Organomet. Chem.*, **2000**, 606, 16.
2. "Ring Opening Metathesis Polymerization of Related Chemistry", NATO Science Series II, **2002**, 23.
3. *Organometallics*, **2003**, 22, 586.

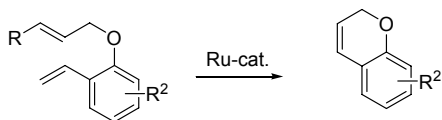
44-0082 **1,3-Bis(2,4,6-trimethylphenyl)-4,5-dihydroimidazol-2-ylidene[2-(i-propoxy)-5-(N,N-dimethylaminosulfonyl)phenyl]methylenruthenium(II) dichloride** **Zhan Catalyst-1B** [918870-76-5]
 $\text{RuCl}_2[\text{C}_{21}\text{H}_{26}\text{N}_2][\text{C}_{12}\text{H}_{17}\text{NO}_3\text{S}]$; FW: 733.75;
 green solid
 Note: Sold under license from Zannan for research purposes only.
 Patents CN1907992A, US 2007/0043180 A1, PCT WO 2007/003135 A1.



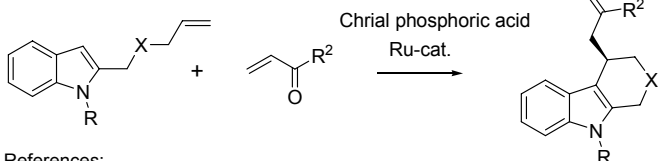
100mg
500mg
2g

Technical Notes:

1. Efficient, air-stable metathesis catalyst.
2. Used in cross-metathesis/Friedel-Crafts Cascade reaction.



Tech. Note (1)



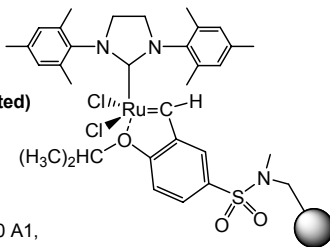
Tech. Note (2)
Ref. (2)

References:

1. PCT Int. Appl. (2007), WO 2007003135 A1
2. *Angew. Chem. Int. Ed.*, **2009**, 48, 7428.

RUTHENIUM (Compounds)

44-0083 **1,3-Bis(2,4,6-trimethylphenyl)-4,5-dihydroimidazol-2-ylidene [2-(i-propoxy)-5-(N,N-dimethylaminosulfonyl)phenyl]methylene-ruthenium(II) dichloride (resin supported) Zhan Catalyst II**
 FW: >1000; black solid;
 Loading: 0.5 mmol/g
 Note: Sold under license from Zannan for research purposes only.
 Patents CN1907992A, US 2007/0043180 A1, PCT WO 2007/003135 A1.

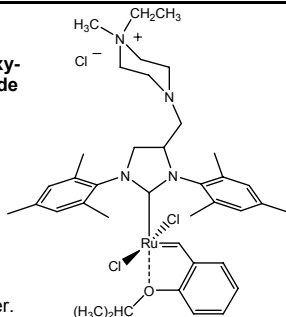


100mg
500mg
2g

Technical Note:

1. See 44-0082 (page 16).

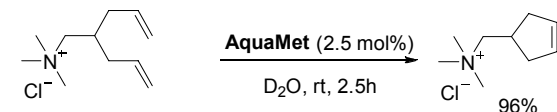
44-0768 **[1,3-Bis(2,4,6-trimethylphenyl)-4-[(4-ethyl-4-methylpiperazin-1-ium-1-yl)methyl]imidazolidin-2-ylidene]-(2-i-propoxybenzylidene)dichlororuthenium(VI) chloride AquaMet [1414707-08-6]**
 $C_{39}H_{55}Cl_3N_4ORu$; FW: 803.31; green powd.
 Note: Sold in collaboration with Apeiron Synthesis, Inc.
 Apeiron Ruthenium Metathesis Catalyst Kit component. See (page 11).



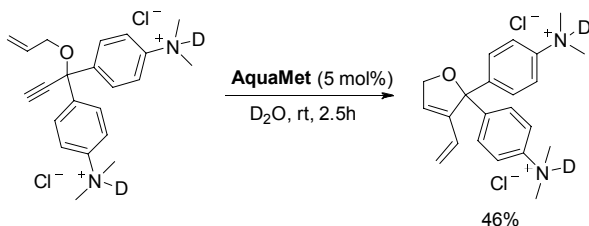
100mg
500mg

Technical Note:

1. Highly active catalyst for olefin metathesis in water.



Tech. Note (1)
Ref. (1)



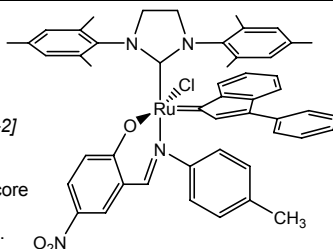
Tech. Note (1)
Ref. (1)

Reference:

1. *Catal. Sci. Technol.*, **2012**, 22, 2424.

RUTHENIUM (Compounds)

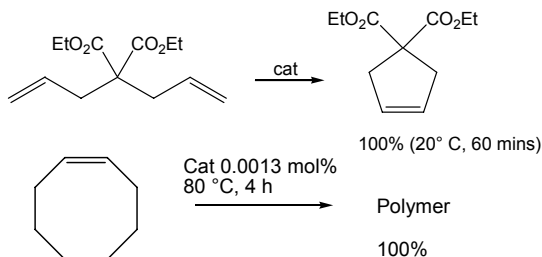
44-0047 [1,3-Bis(2,4,6-trimethylphenyl)-2-imidazolidinylidene]-2-[[[(4-methylphenyl)imino]methyl]-4-nitrophenolyl]-[3-phenyl-1H-inden-1-ylidene]ruthenium(II) chloride [934538-04-2]
 $C_{50}H_{47}ClIN_4O_3Ru$; FW: 888.46;
 orange-brown solid
 Note: Sold in collaboration with Umicore for research purposes only.
 EP 1 468 004 B1, US 2002/0349956.



100mg
500mg

Technical Note:

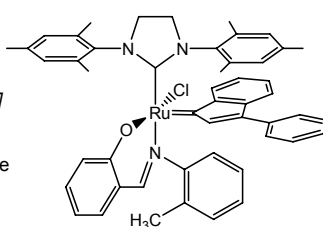
1. Highly active catalyst for ring opening and ring closing metathesis reactions.



References:

1. WO 2003062253.
2. *Eur. J. Org. Chem.*, **2009**, 655.
3. *Curr. Org. Synth.*, **2008**, 5, 291.

44-0049 [1,3-Bis(2,4,6-trimethylphenyl)-2-imidazolidinylidene]-2-[[[(2-methylphenyl)imino]methyl]phenolyl]-[3-phenyl-1H-inden-1-ylidene]ruthenium(II) chloride [934538-12-2]
 $C_{50}H_{48}ClIN_3ORu$; FW: 843.46;
 red-brown solid
 Note: Sold in collaboration with Umicore for research purposes only.
 EP 1 468 004 B1, US 2002/0349956.



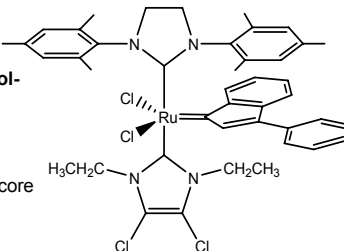
100mg
500mg

Technical Note:

1. See 44-0047 (page 18).

44-0026**NEW→**

1,3-Bis(2,4,6-trimethylphenyl)-2-imidazolidinylidene(3-phenyl-1H-inden-1-ylidene)(4,5-dichloro-1,3-diethyl-1,3-dihydro-2H-imidazol-2-ylidene)ruthenium(II) chloride [1228169-92-3]
 $C_{43}H_{46}Cl_2N_4Ru$; FW: 861.73;
 orange-brown solid
 Note: Sold in collaboration with Umicore for research purpose only.
 Patent US 10,873,026.



50mg
250mg
1g

Technical Note:

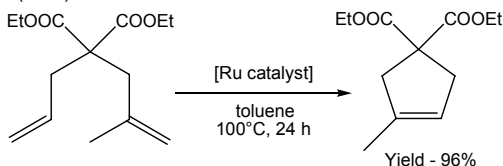
1. Catalyst used for RCM reactions leading to tetrasubstituted olefins.

RUTHENIUM (Compounds)

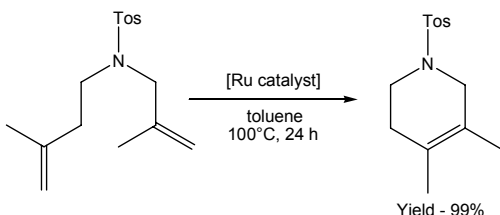
44-0026

NEW→
(cont.)

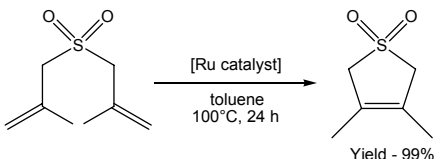
1,3-Bis(2,4,6-trimethylphenyl)-2-imidazolidinylidene(3-phenyl-1H-inden-1-ylidene)(4,5-dichloro-1,3-diethyl-1,3-dihydro-2H-imidazol-2-ylidene)ruthenium(II) chloride
[1228169-92-3]



Tech. Note (1)
Ref. (1)



Tech. Note (1)
Ref. (1)



Tech. Note (1)
Ref. (1)

Reference:

1. *Organometallics*, **2010**, 29, 2761.

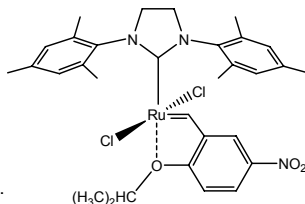
44-0758

NEW→

[1,3-Bis(2,4,6-trimethylphenyl-imidazolidin-2-ylidene)]-(2-*i*-propoxy-5-nitrobenzylidene)ruthenium(VI) dichloride nitro-Grela [502964-52-5]

C₃₁H₃₇Cl₂N₃O₃Ru; FW: 671.62;
green powdr.

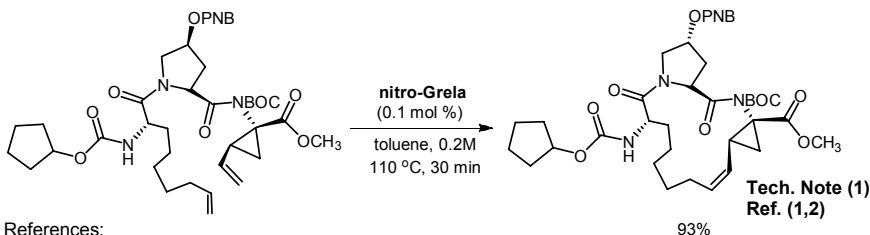
Note: Sold in collaboration with Apeiron
Synthesis, Inc. Apeiron Ruthenium
Metathesis Kit component. See (page 11).



100mg
500mg

Technical Notes:

1. Catalyst used for an efficient synthesis of HCV Protease Inhibitor, BILN 2061.
2. The nitro-Grela catalyst is a stable olefin metathesis initiator active in various ring-closing, cross, and enyne metathesis reactions. Its efficiency has been proven in numerous total syntheses of natural and biologically active compounds, and in material science.



Tech. Note (1)
Ref. (1,2)

References:

1. *Org. Lett.*, **2008**, 1, 1303.
2. *Org. Process Res. Dev.*, **2009**, 13, 250.
3. *Org. Lett.*, **2010**, 12, 248.
4. *Angew. Chem. Int. Ed.*, **2008**, 47, 6483.
5. *Tetrahedron Lett.*, **2006**, 47, 6351.
6. *J. Am. Chem. Soc.*, **2004**, 126, 9318.
7. *Angew. Chem. Int. Ed.*, **2002**, 41, 4038.

RUTHENIUM (Compounds)

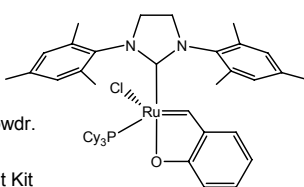
44-0753

NEW→

[1,3-Bis(2,4,6-trimethylphenyl-imidazolidin-2-ylidene)] (tricyclohexylphosphine)-(2-oxobenzylidene)ruthenium(VI) chloride LatMet [1407229-58-6]

$C_{46}H_{65}ClN_2OPRu$; FW: 829.52; green powdr.

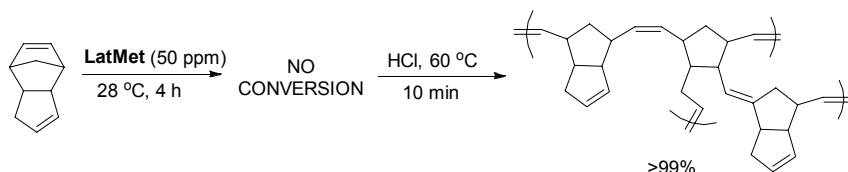
Note: Sold in collaboration with Apeiron Synthesis, Inc. Apeiron Ruthenium Metathesis Catalyst Kit component. See (page 11).



100mg
500mg

Technical Note:

1. Catalyst used for olefin metathesis polymerization.



Reference:

1. *Chem. Eur. J.*, **2014**, *20*, 1.

Tech. Note (1)

Ref. (1)

44-0765

NEW→

[1,3-Bis(2,4,6-trimethyl-phenyl)-4-[(trimethylammonio)methyl]imidazolidin-2-ylidene]-(2-i-propoxy-5-benzylidene) dichlororuthenium(VI) chloride StickyCat Cl [1452227-72-3]

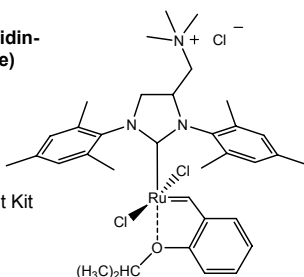
$C_{35}H_{48}Cl_2N_3O_2Ru$; FW: 734.20;

green powdr.

Note: Sold in collaboration with

Apeiron Synthesis, Inc.

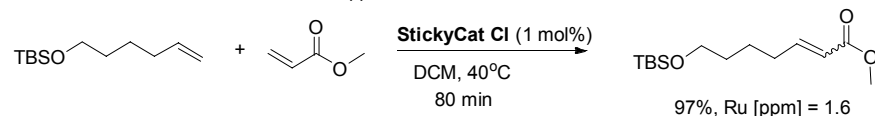
Apeiron Ruthenium Metathesis Catalyst Kit component. See (page 11).



100mg
500mg

Technical Note:

1. Easily removable olefin metathesis catalyst.
High activity at 40-110 °C
Residual ruthenium metal <0.004ppm.



Reference:

1. *Green Chem.*, **2012**, *14*, 3264.

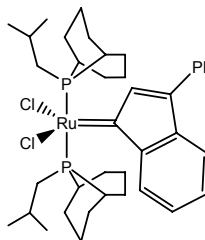
Ref. (1)

44-7778

3-Phenyl-1H-inden-1-ylidene [bis(i-butylphoban)]ruthenium(II) dichloride [894423-99-5]

$C_{39}H_{56}Cl_2P_2Ru$; FW: 758.78; red powdr.

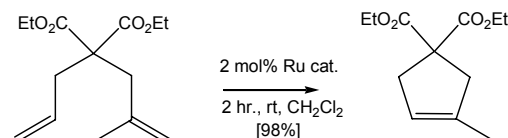
Note: Sold in collaboration with Umicore for research purposes only. Patent US 10,518,716.



250mg
1g

Technical Note:

1. This catalyst exhibits high selectivity as a general purpose metathesis catalyst for applications other than polymerization. It has improved air, moisture and heat resistance.



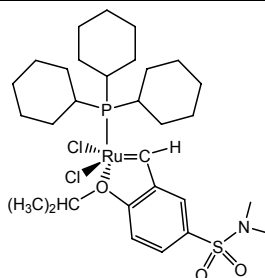
Reference:

1. *J. Org. Chem.*, **2008**, *73*, 259.

RUTHENIUM (Compounds)

44-0078 {[2-(i-propoxy)-5-(N,N-dimethylaminosulfonyl)phenyl]methylene}(tricyclohexylphosphine) ruthenium(II) dichloride **Zhan Catalyst -1C** [918871-44-0]

$C_{30}H_{50}Cl_2NO_3PRuS$; FW: 707.74; brown solid
Note: Sold under license from Zannan for research purposes only. Patents CN1907992A, US 2007/0043180 A1, PCT WO 2007/003135 A1.



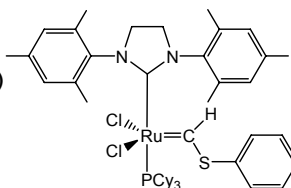
500mg
2g

Technical Note:

- See 44-0082 (page 16).

44-7780 **Tricyclohexylphosphine** [1,3-bis(2,4,6-trimethylphenyl)-4,5-dihydroimidazol-2-ylidene] [(phenylthio)methylene]ruthenium(II) dichloride [1155422-69-7]

$RuCl_2[C_{21}H_{26}N_2][C_7H_6S][P(C_6H_{11})_3]$; FW: 881.04; purple-brown solid
Note: Sold in collaboration with BASF for research purposes only.
Patents US 6,407,190 and EP 993,465.



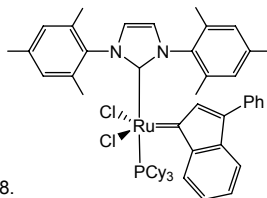
100mg
500mg

Technical Note:

- See 44-0073 (page 16).

44-7775 **Tricyclohexylphosphine** [1,3-bis(2,4,6-trimethylphenyl)imidazol-2-ylidene][3-phenyl-1H-inden-1-ylidene] ruthenium(II) dichloride, min. 95% [catMETium® RF1] [254972-49-1]

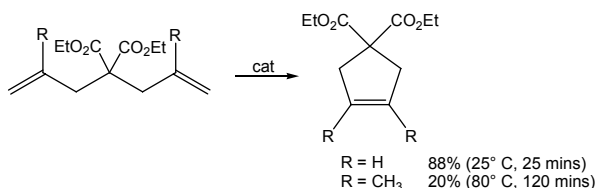
$RuCl_2[C_{21}H_{24}N_2][C_{15}H_{10}][P(C_6H_{11})_3]$; FW: 947.07; orange to brown pwr.
Note: Sold in collaboration with Evonik for research purposes only. Patent US 6635768.
For use in pharmaceutical applications only.
Other uses are unauthorized.



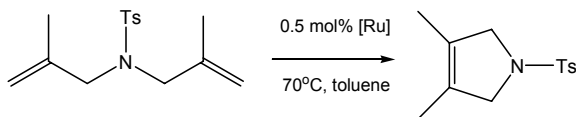
100mg
500mg
2g

Technical Note:

- Efficient catalyst for ring-closing metathesis.



Ref. (1)



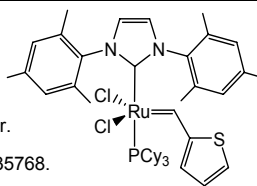
Ref. (2)

References:

- Organometallics*, **1999**, 18, 5416.
- ChemistryToday*, **2009**, 27, 24.

RUTHENIUM (Compounds)

44-7785 Tricyclohexylphosphine[1,3-bis(2,4,6-trimethylphenyl)imidazol-2-ylidene][2-thienylmethylene]ruthenium(II) dichloride, min. 95% [catMETium® RF 2] [1190427-49-6]
 $C_{44}H_{61}Cl_2N_2PRuS$; FW: 852.98; brown powdr.
 Note: Sold in collaboration with Evonik for research purposes only. Patent US 6635768.

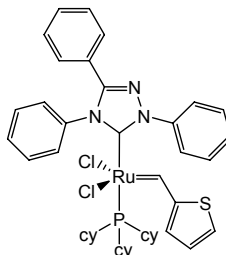


100mg
500mg
2g

Technical Note:

1. See 44-7775 (page 21).

44-7795 Tricyclohexylphosphine[2,4-dihydro-2,4,5-triphenyl-3H-1,2,4-triazol-3-ylidene][2-thienylmethylene]ruthenium(II) dichloride, min. 95% [catMETium® RF 4] [1190427-51-0]
 $C_{43}H_{52}Cl_2N_3PRuS$; FW: 845.91;
 violet to brown powdr.



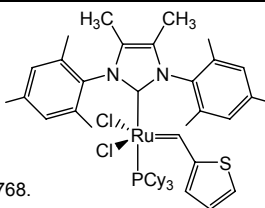
100mg
500mg
2g

Note: Sold in collaboration with Evonik for research purposes only. Patent US 6635768.

Technical Note:

1. See 44-7775 (page 21).

44-7790 Tricyclohexylphosphine[4,5-dimethyl-1,3-bis(2,4,6-trimethylphenyl)imidazol-2-ylidene][2-thienylmethylene]ruthenium(II) dichloride, min. 95% [catMETium® RF 3] [1190427-50-9]
 $C_{46}H_{65}Cl_2N_2PRuS$; FW: 881.04;
 violet to brown powdr.



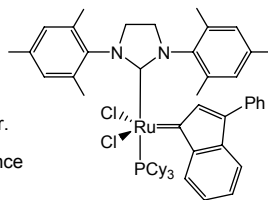
100mg
500mg
2g

Note: Sold in collaboration with Evonik for research purposes only. Patent US 6635768.

Technical Note:

1. See 44-7775 (page 21).

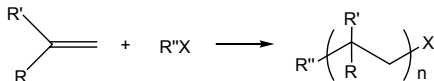
44-7777 Tricyclohexylphosphine[3-phenyl-1H-inden-1-ylidene][1,3-bis(2,4,6-trimethylphenyl)-4,5-dihydroimidazol-2-ylidene]ruthenium(II) dichloride, min. 95% [536724-67-1]
 $C_{54}H_{69}Cl_2N_2PRu$; FW: 949.09; dark red powdr.
 Note: Sold in collaboration with Umicore for research purposes only. For use in lifescience applications and research purposes only.



100mg
500mg

Technical Note:

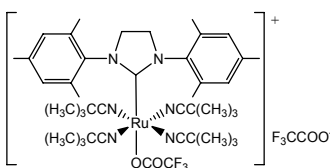
1. Catalyst used for the Atom Transfer Radical Polymerization (ATRP) of vinyl monomers.



Reference:

1. *New J. Chem.*, **2003**, 27, 257.

44-7712 Trifluoroacetato[4,5-dihydro-1,3-bis(2,4,6-trimethylphenyl)imidazol-2-ylidene]tetra(2,2-dimethylpropanenitrile)ruthenium(II) trifluoroacetate [1034198-65-6]
 $C_{45}H_{62}F_6N_6O_4Ru$; FW: 966.08;
 yellow xtl.
air sensitive



100mg
500mg

Note: Sold under license from ITCF

for research purposes only. DE 102008008299, US 12/866.806.

Technical Note:

1. Cationic ruthenium(II) complex useful for UV-induced, ring-opening metathesis polymerization.

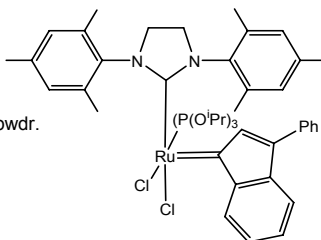
Reference:

1. *Angew. Chem. Int. Ed.*, **2008**, 47, 3267.

RUTHENIUM (Compounds)

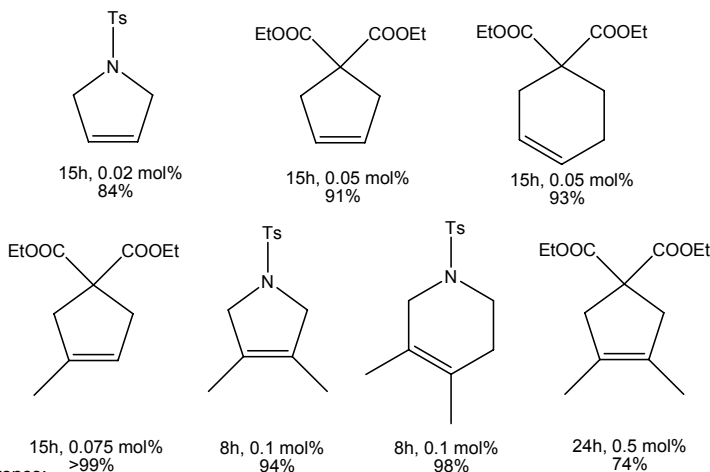
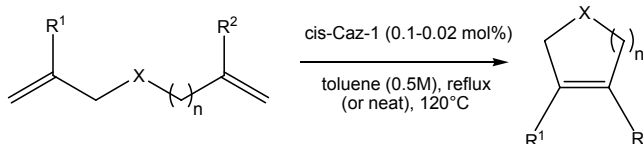
44-7783 Tri(*i*-propoxy)phosphine(3-phenyl-1*H*-inden-1-ylidene)[1,3-bis(2,4,6-trimethylphenyl)-4,5-dihydroimidazol-2-ylidene]ruthenium (II) dichloride, min. 95% **cis-Caz-1**
 $C_{45}H_{57}Cl_2N_2O_3Ru$; FW: 876.89; brown powdr.

50mg
250mg



Technical Note:

- Efficient catalyst for ring-closing metathesis.



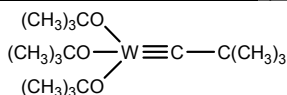
Reference:

- Chem. Commun.*, **2010**, 7115.

Metathesis Catalysts Available from Strem

TUNGSTEN (Compounds)

74-1800 Tris(*t*-butoxy)(2,2-dimethylpropylidene)tungsten(VI), 98%
 amp
Schrock Alkyne Metathesis Catalyst
 [78234-36-3]
 $(C_4H_9O)_3W=CC(CH_3)_3$; FW: 472.31;
 off-white to tan powdr.
air sensitive, moisture sensitive, (store cold)



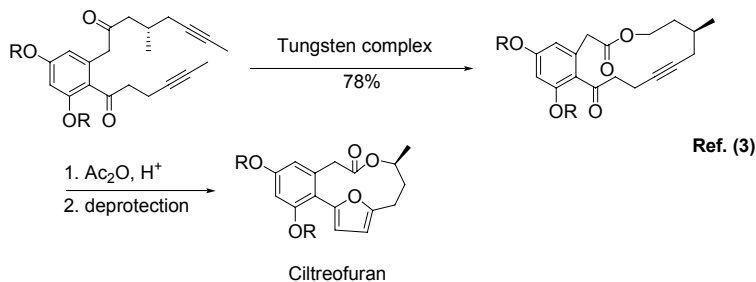
100mg
500mg

Technical Notes:

- A well-defined tungsten-based alkyne metathesis catalyst first prepared by Professor Richard Schrock. The catalyst has been used to prepare a variety of products through alkyne metathesis, including natural products that contain large rings.
- Catalyst for living polymerization of strained alkynes.

TUNGSTEN (Compounds)

74-1800 **Tris(*t*-butoxy)(2,2-dimethylpropylidyne)tungsten(VI), 98%**
 amp **Schrock Alkyne Metathesis Catalyst [78234-36-3]**
 (cont.)



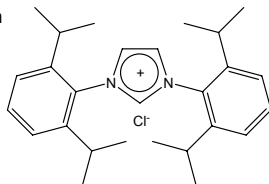
References:

1. *Acc. Chem. Res.*, **1986**, 19, 342. (review article)
2. *Angew. Chem. Int. Ed.*, **2000**, 39, 3012. (review article)
3. *J. Org. Chem.*, **2003**, 68, 1521.
4. *Angew. Chem., Int. Ed.*, **2010**, 49, 7257.

NITROGEN (Compounds)

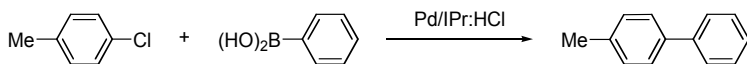
07-0590 1,3-Bis(2,6-di-*i*-propylphenyl)imidazolium chloride, min. 97% [250285-32-6]
 $C_{27}H_{37}N_2^+Cl^-$; FW: 425.06;
 white to off-white powdr.
 Note: NHC Ligand Kit 3:
 Variety of N-Heterocyclic Carbenes Kit
 component. Visit strem.com.

500mg
2g

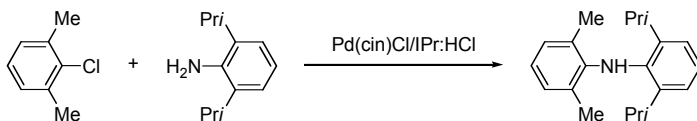


Technical Notes:

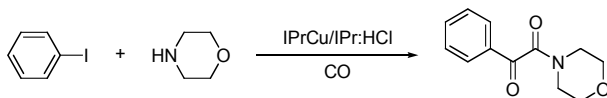
1. Precursor to Pd catalysts used in C-N and C-C coupling reactions.
2. Ligand used in double carbonylation reactions.
3. Precursor to Ni catalysts used in C-N coupling reactions.
4. Precursor to Cu catalysts used in copper hydride reactions.
5. Ligand used in Ru-catalyzed carbonylative C-H cyclization of 2-aryl phenols.



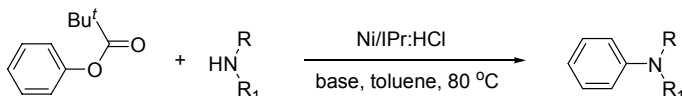
Tech. Note (1)
Ref. (1,2,4)



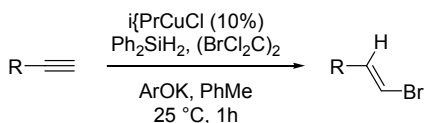
Tech. Note (1)
Ref. (2)



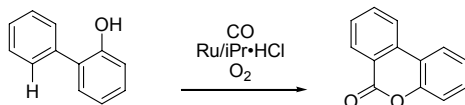
Tech. Note (2)
Ref. (3)



Tech. Note (3)
Ref. (5,6)



Tech. Note (4)
Ref. (8)



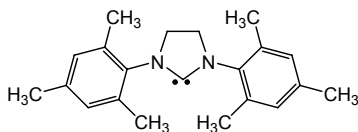
Tech. Note (5)
Ref. (9)

References:

1. *Organometallics*, **2002**, 21, 2866.
2. *J. Am. Chem. Soc.*, **2006**, 128, 4101.
3. *Org. Lett.*, **2009**, 11, 1321.
4. *Angew. Chem., Int. Ed.*, **2012**, 51, 2.
5. *Angew. Chem., Int. Ed.*, **2011**, 50, 2171.
6. *Angew. Chem., Int. Ed.*, **2010**, 49, 2929.
7. See 07-0299 (page 26).
8. *J. Am. Chem. Soc.*, **2014**, 136, 8799.
9. *Org. Lett.*, **2013**, 15, 3962.

NITROGEN (Compounds)

07-0605 **1,3-Bis(2,4,6-trimethylphenyl)-4,5-dihydroimidazol-2-ylidene**, min. 98% [173035-11-5]
 $C_{21}H_{26}N_2$; FW: 306.45;
 white to off-white powdr.
air sensitive, moisture sensitive
 Note: NHC Ligand Kit 2:
 "Free" Carbenes Kit component. Visit strem.com.

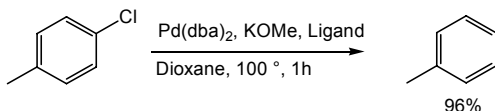


500mg
2g

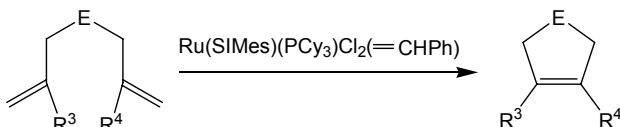
Technical Notes:

1. Nucleophilic carbene that serves as a bulky, electron-rich "phosphine mimic" for metal-catalyzed reactions.

(a) Palladium- Catalyzed dehalogenation of aryl halides using carbene precursor SiMes.HCl.

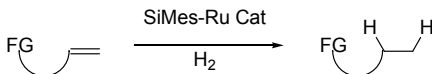


(b) Ruthenium- SiMes is part of the Grubbs II Ruthenium catalyst for ring-closing metathesis Ref. (2,3). The catalyst $RuHCl(CO)SiMes(PPh_3)$ has been used for hydrogenation of unactivated internal olefins (Ref 4).



(c) Copper- The presence of SiMes greatly accelerates the catalyzed conjugate addition of diethylzinc to enones (Ref 5). Cu-SiMes complexes are good hydrosilylation catalysts for hindered and functionalized ketones (Ref. 6).

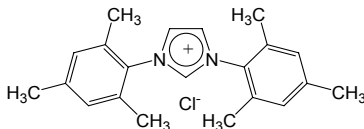
2. Mixed carbene ruthenium hydride complex as an olefin-selective hydrogenation catalyst.



References:

1. *Organometallics*, **2001**, 20, 3607.
2. *Org. Lett.*, **1999**, 1, 953.
3. *Angew. Chem. Int. Ed.*, **2006**, 45, 3760.
4. *Organometallics*, **2005**, 24, 1056.
5. *Tetrahedron Lett.*, **2001**, 42, 2747.
6. *J. Org. Chem.*, **2005**, 70, 4784.
7. *Organometallics*, **2012**, 31, 802.

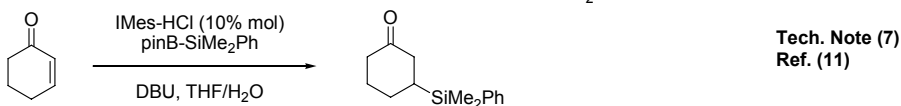
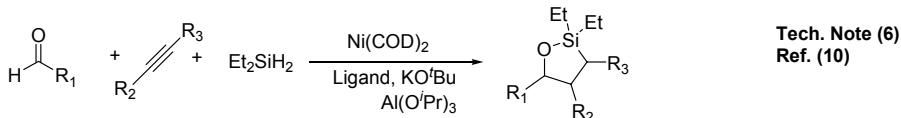
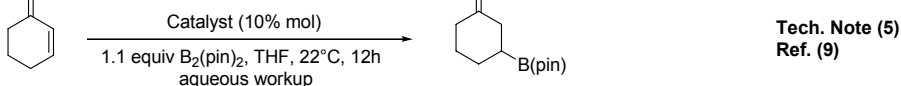
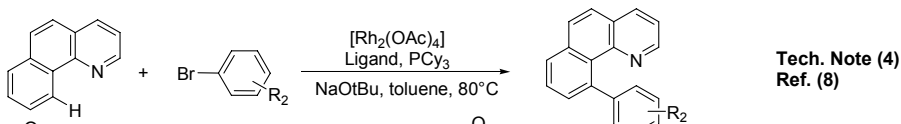
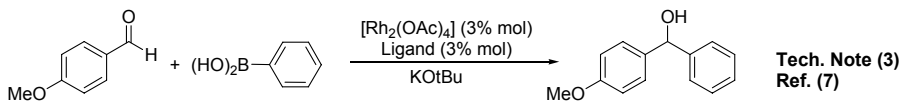
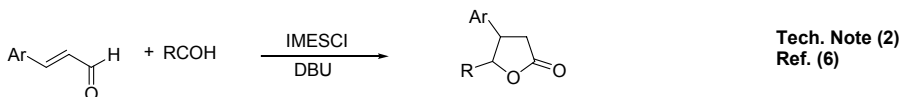
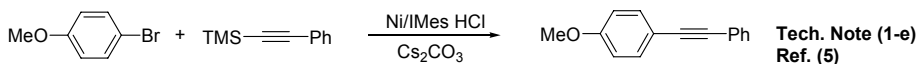
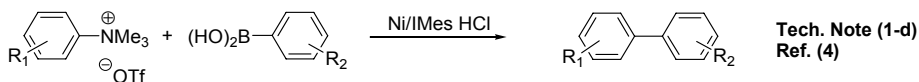
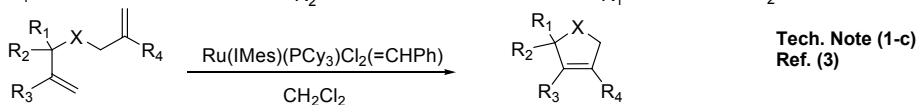
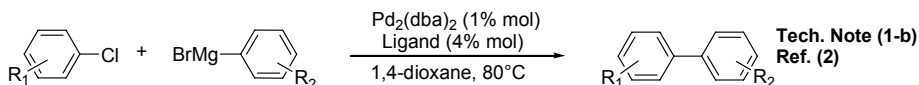
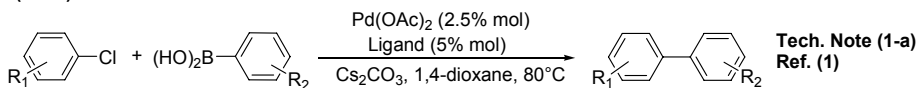
07-0299 **1,3-Bis(2,4,6-trimethylphenyl)imidazolium chloride**, min. 97%
 [141556-45-8]
 $C_{21}H_{25}N_2^+Cl^-$; FW: 340.90;
 off-white to yellow powdr.
 Note: NHC Ligand Kit 3:
 Variety of N-Heterocyclic Carbenes Kit component. Visit strem.com.



1g
5g

Technical Notes:

1. Precursor to the nucleophilic carbene that serves as a bulky, electron-rich "phosphine mimic" for metal-catalyzed reactions.
 - (a) Palladium-catalyzed Suzuki cross-coupling of aryl chlorides.
 - (b) Palladium-catalyzed Kumada cross-coupling of aryl chlorides.
 - (c) Ruthenium-carbene catalysts for ring-closing metathesis.
 - (d) Suzuki coupling of aryltrimethylammonium salts.
 - (e) Sonogashira coupling of aryl bromides.
2. Precursor to a nucleophilic carbene that serves as catalyst.
3. Ligand for arylation of aldehydes.
4. Ligand for carbene catalyzed intermolecular arylation of C-H bonds.
5. Catalyst for boron conjugate additions to cyclic and acyclic α,β -unsaturated carbonyls.
6. Ligand for dehydrogenative cyclocondensation of aldehydes, alkynes, and dialkylsilanes.
7. Precursor for carbene for conjugate silylation of alpha, beta-unsaturated carbonyls.

NITROGEN (Compounds)**07-0299** 1,3-Bis(2,4,6-trimethylphenyl)imidazolium chloride, min. 97% [141556-45-8]
(cont.)

References:

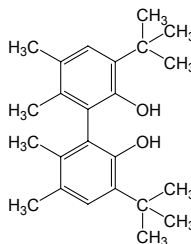
1. *Organometallics*, **2002**, 21, 2866.
2. *J. Am. Chem. Soc.*, **1999**, 121, 9889.
3. *Org. Lett.*, **2000**, 2, 1517.
4. *J. Am. Chem. Soc.*, **2003**, 125, 6046.
5. *Organometallics*, **2002**, 21, 1020.
6. *J. Am. Chem. Soc.*, **2004**, 126, 14370.
7. *Angew. Chem. Int. Ed.*, **2007**, 46, 5750.
8. *Angew. Chem. Int. Ed.*, **2009**, 48, 8935.
9. *J. Am. Chem. Soc.*, **2009**, 131, 7253.
10. *J. Am. Chem. Soc.*, **2008**, 130, 9662.
11. *J. Am. Chem. Soc.*, **2011**, 133, 7712.

OXYGEN (Compounds)

19-1600 (R)-(-)-5,5',6,6',7,7',8,8'-Octahydro-3,3'-di-*t*-butyl-1,1'-bi-2-naphthol, dipotassium salt
See (page 29).

19-1601 (S)-(+)-5,5',6,6',7,7',8,8'-Octahydro-3,3'-di-*t*-butyl-1,1'-bi-2-naphthol, dipotassium salt
See (page 29).

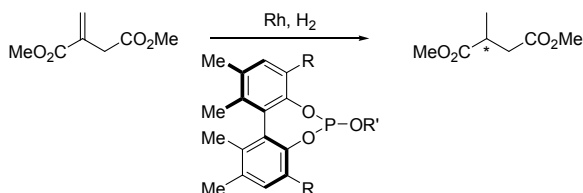
08-2045 racemic-5,5',6,6'-Tetramethyl-3,3'-di-*t*-butyl-1,1'-biphenyl-2,2'-diol, 99% rac-BIPHEN H₂
[101203-31-0]
C₂₄H₃₄O₂; FW: 354.54; white to off-white xtl.;
m.p. 163-165°



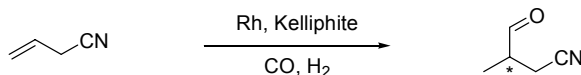
5g
25g

Technical Notes:

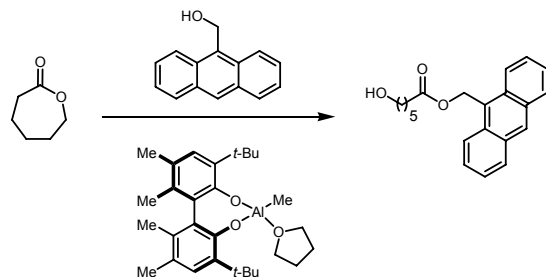
1. Used as a ligand backbone for metathesis catalysts.
2. Used as a ligand backbone in catalytic asymmetric hydrogenation.
3. Used as a ligand backbone for asymmetric hydroformylation of allyl cyanide.
4. Used as a ligand backbone for phosphoramidite ligands in the asymmetric Rh-catalyzed [2+2+2] cycloaddition.
5. Used as a ligand backbone for the ring-opening polymerization of cyclic esters.



Tech. Note (2)
Ref. (2)



Tech. Note (3)
Ref. (3)



Tech. Note (5)
Ref. (5,6)

References:

1. See 42-1212 (page).
2. *Org. Lett.*, **2003**, 5, 3831.
3. *J. Org. Chem.*, **2004**, 69, 4031.
4. *Angew. Chem. Int. Ed.*, **2009**, 48, 2379.
5. *J. Polym. Sci. Pol. Chem.*, **2010**, 48, 3564.
6. *J. Organomet. Chem.*, **2012**, 716, 175.

08-2046 (R)-(+)-5,5',6,6'-Tetramethyl-3,3'-di-*t*-butyl-1,1'-biphenyl-2,2'-diol, 99% (R)-BIPHEN H₂ [329735-68-4]
C₂₄H₃₄O₂; FW: 354.54; white powdr.; [α]_D +78° (c 0.352, THF)

100mg
500mg
2g

Technical Note:

1. See 42-1214 (page 14).

08-2047 (S)-(-)-5,5',6,6'-Tetramethyl-3,3'-di-*t*-butyl-1,1'-biphenyl-2,2'-diol, 99% (S)-BIPHEN H₂ [205927-03-3]
C₂₄H₃₄O₂; FW: 354.54; white powdr.; [α]_D -78° (c 0.352, THF)

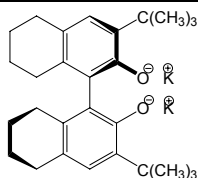
100mg
500mg
2g

Technical Note:

1. See 42-1214 (page 14).

POTASSIUM (Compounds)

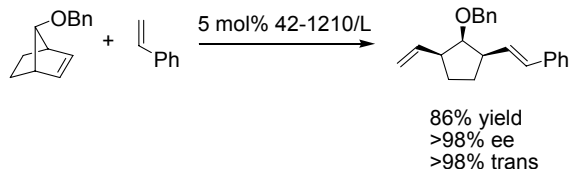
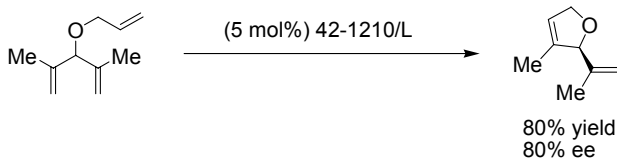
19-1600 (R)-(-)-5,5',6,6',7,7',8,8'-Octahydro-3,3'-di-t-butyl-1,1'-bi-2-naphthol, dipotassium salt [350683-75-9]
 $C_{28}H_{36}K_2O_2$; FW: 482.80;
 cream-colored powdr.; $[\alpha]_D -35^\circ$ (c 1, THF)
moisture sensitive



100mg
500mg

Technical Note:

- Ligand used in combination with 42-1210 (see page 13) for asymmetric ring closing and ring opening metathesis.



Reference:

- Angew. Chem. Int. Ed.*, **2001**, 40(8), 1452.

19-1601 (S)-(+)-5,5',6,6',7,7',8,8'-Octahydro-3,3'-di-t-butyl-1,1'-bi-2-naphthol, dipotassium salt
 $C_{28}H_{36}K_2O_2$; FW: 482.80; cream-colored powdr.; $[\alpha]_D +35^\circ$ (c 1, THF)
moisture sensitive

100mg
500mg

Technical Note:

- See 19-1600 (page 29).

PROVIVI CARBENE/NITRENE TRANSFERASE SCREENING KIT

96-1580

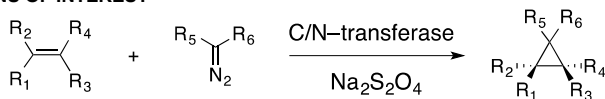
Provivi Carbene/Nitrene Transferase Screening Kit

NEW→

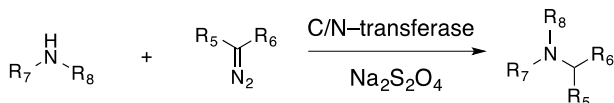
Sold under license from Provivi for research purposes only.

Contains the following:

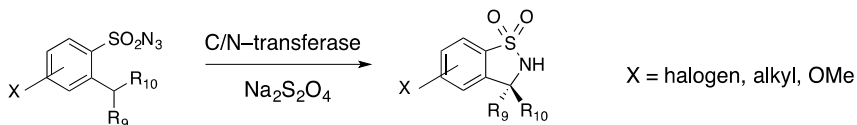
1. REACTIONS OF INTEREST



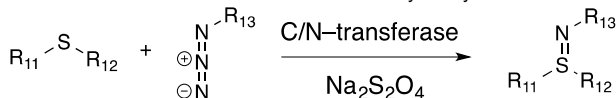
Synthesis of cyclopropanes via carbene transfer catalyzed by carbene/nitrene transferases.



Synthesis of substituted amines via carbene transfer catalyzed by carbene/nitrene transferases.



Synthesis of substituted benzosultams via nitrene transfer catalyzed by carbene/nitrene transferases.



Synthesis of sulfimides via nitrene transfer catalyzed by carbene/nitrene transferases.

2. PROVIVI C/N TRANSFERASE SCREENING KIT GENERAL INFORMATION

Natural enzymes have traditionally catalyzed only a small subset of the chemical reactions that are needed for synthesis of key agrochemicals and pharmaceuticals. To address this challenge, we have engineered heme enzymes that perform carbene and nitrene transfer, the carbon and nitrogen analogues of cytochrome P450's native monooxygenation chemistry. Our heme enzymes can efficiently activate diazo and azide compounds to generate iron-carbenoids and iron-nitrenoids, respectively, through a mode of activation that has never been observed in nature. These intermediates can react with a variety of substrates such as olefins, N-H bonds, C-H bonds, and sulfides, offering great synthetic utility. After identifying initial activity on a reaction of interest, these catalysts can be engineered (e.g. via directed evolution) to achieve high activities and stereoselectivities.

The cyclopropanation instructions described in this technical note can be readily adapted for the other reactions outlined above. All reactions must be performed under anaerobic conditions. The cyclopropanes are synthesized by the reaction of a diazo-type carbene precursor (e.g. ethyl diazoacetate) with olefins (e.g. styrene) using carbene/nitrene transferases as catalyst.

PROVIVI CARBENE/NITRENE TRANSFERASE SCREENING KIT (cont.)**PROVIVI C/N TRANSFERASE SCREENING KIT CONTENTS**

Enzyme	Amount (350 μ L kit) Strem Cat. #96-1580
PRVV-001	350 μ L
PRVV-002	350 μ L
PRVV-003	350 μ L
PRVV-004	350 μ L
PRVV-005	350 μ L
PRVV-006	350 μ L
PRVV-007	350 μ L
PRVV-008	350 μ L
PRVV-009	350 μ L
PRVV-010	350 μ L
PRVV-011	350 μ L
PRVV-012	350 μ L
PRVV-013	350 μ L
PRVV-014	350 μ L
PRVV-015	350 μ L
PRVV-016	350 μ L
PRVV-017	350 μ L
PRVV-018	350 μ L
PRVV-019	350 μ L
PRVV-020	350 μ L
PRVV-021	350 μ L
PRVV-022	350 μ L
PRVV-023	350 μ L
PRVV-024	350 μ L
PRVV-025	350 μ L
PRVV-026	350 μ L
PRVV-027	350 μ L
PRVV-028	350 μ L
PRVV-029	350 μ L
PRVV-030	350 μ L
PRVV-031	350 μ L
PRVV-032	350 μ L

The catalyst should be stored at -20°C in potassium phosphate buffer (100 mM, pH 8.0) as provided. The catalyst is stable for over 1 year under these conditions.

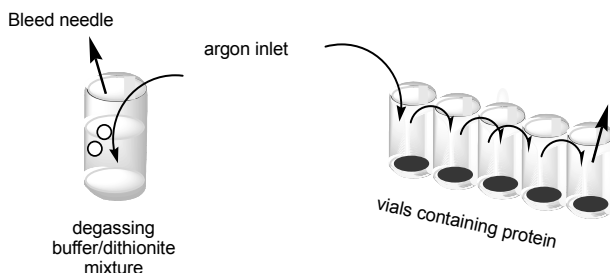
SCREENING REAGENTS

- 2.1. **Provivi C/N transferase(350 μ L, 133 μ M), provided in the kit**
- 2.2. **100 mM Potassium phosphate buffer, pH 8.0**
- 2.3. **12.5 mM Sodium Dithionite ($\text{Na}_2\text{S}_2\text{O}_4$)**
- 2.4. **Solvent: ethanol, methanol or DMSO**
- 2.5. **400 mM Ethyl Diazoacetate (or another carbene/nitrene precursor)**
- 2.6. **800 mM Styrene (or another olefin, amine, or sulfide substrate)**

3. ADDITIONAL TOOLS AND EQUIPMENT

In the absence of an anaerobic chamber, the tools and equipment below can be used to implement anaerobic conditions in small reaction vials.

Tool/Equipment	Use
Teflon sealed crimp vials and caps	Individual small scaled reactions should be carried out in Teflon sealed crimp vials.
Argon manifold with multiple ports that can be adapted to needle outlets	Argon line is used to purge the headspace of each individual vial and to degas the sodium dithionite solution through bubbling.
Shaker	Reactions are shaken for 4-12 hours on table top shakers at room temperature.

PROVIVI CARBENE/NITRENE TRANSFERASE SCREENING KIT (cont.)**3.1. Experimental set up for degassing buffer and protein.****4. SCREENING PROCEDURE**

- 4.1. Reactions are performed in 1.5 mL crimp vials with Teflon seal caps. Each reaction has a final volume of approximately 400 μ L, including 10 μ L of olefin and 10 μ L of diazo compound in the cosolvent of choice (e.g. EtOH, MeOH or DMSO, depending on the solubility of the olefin substrate), 380 μ L of sodium dithionite and C/N transferase in potassium phosphate buffer. Final concentrations are: diazo compound (10 mM), olefin (20 mM), sodium dithionite (10 mM), C/N transferase (20 μ M), and cosolvent (5% v/v).
- 4.2. Thaw the provided solutions of C/N transferase on ice.
- 4.3. Prepare the sodium dithionite solution on the day of the experiment.
- 4.3.1. Prepare the 100 mM potassium phosphate buffer, dissolve 13.6 g of potassium phosphate monobasic and 1 g of potassium phosphate dibasic in 1 L of dd H₂O, adjust the pH to 8.0 using KOH.
- 4.3.2. In a crimp vial, solid sodium dithionite is massed then dissolved in 100 mM potassium phosphate buffer, pH 8.0, such that the final concentration of sodium dithionite is 12.5 mM (this is about 2.2 mg of sodium dithionite per mL of potassium phosphate buffer). Seal the vial with a Teflon cap.
- 4.4. Add 60 μ L of the C/N transferase solution to a separate crimp vial. The vials are capped and sealed.
- 4.5. The headspace of the vial containing protein is purged with argon. Do not bubble the proteins directly. If multiple protein reactions are to be performed in parallel, up to 8 reaction vials can be connected in series using cannula (20 gauge or higher needle tips). The sodium dithionite solution is degassed via direct bubbling for 5-10 minutes. At the end of this time, the degassed dithionite solution (320 μ L) is added to each reaction vial containing the C/N transferase.
- 4.6. Remove the cannulas, starting from the connections that are furthest from the argon source.
- 4.7. Substrates are added as stock solutions. A 400 mM stock solution of the diazo component (e.g. EDA) and 800 mM stock solution of the olefin substrate (e.g. styrene) are prepared in a suitable co-solvent. The olefin stock (10 μ L) is added to each vial followed by the diazo component stock (10 μ L).
- 4.8. The reactions are shaken at room temperature at 30 rpm for at least 4 h.

5. REACTION WORK UP AND ANALYSIS

- 5.1. The reaction is quenched by the addition of 25 μ L of 3 M HCl (provided that the desired product is tolerant of acidic conditions) to each individual reaction via syringe.
- 5.2. The vials are decapped and an internal standard (such as phenethyl alcohol, 20 mM, 20 μ L) is added.
- 5.3. Cyclohexane (1mL) is added to each vial and the aqueous/organic mixture is transferred to a 1.8 mL Eppendorf tube.
- 5.4. The tubes are vortexed then centrifuged at 13,000xg for 1 min.
- 5.5. The organics are removed and analyzed by GC, GC-MS, or normal phase HPLC, depending on the MW and molecular composition of the product.
- 5.6. For reverse phase HPLC, the cyclohexane addition in step 5.3 should be substituted for the addition of at least 400 μ L of acetonitrile.
- 5.7. For the reaction of EDA with styrene, the product can be observed by chiral phase GC using a Cyclosil-B column (30 m x 0.32 mm x 0.25 μ m): injection temperature = 300 $^{\circ}$ C, oven temperature = 100 $^{\circ}$ C 5 min, 1 $^{\circ}$ C / min to 135 $^{\circ}$ C, 135 $^{\circ}$ C 10 min, 10 $^{\circ}$ C / min to 200 $^{\circ}$ C, 200 $^{\circ}$ C 5 min, *cis*-cyclopropanes (39.40 min (1S, 2R) and 40.20 min (1R, 2S)), *trans*-cyclopropanes (44.69 min (1R, 2R) and 45.00 min (1S, 2S)).
- 5.8. A positive control can be performed following the procedure above using enzyme PRVV-001, styrene and EDA. The table below shows typical reaction results.

PROVIVI CARBENE/NITRENE TRANSFERASE SCREENING KIT (cont.)

Cat.	Olefin	Carbene	C _(olefin) [mM]	C _(EDA) [mM]	C _(cat) [μM]	C _(prod) [mM]	C _(prod) [g/L]	Yield [%]	E:Z	%ee _z [%]	TTN	time [h]	vol. productivity [g/L/h]
PRVV-001	Styrene	EDA	20	10	20	5-7	0.95-1.33	50-70	29:71	92	250-350	4	0.24-0.33

6. TROUBLESHOOTING/FAQ

For questions not addressed in the following FAQ, contact us at sales@provivi.com

Problem: low reactivity

Possible causes:

- (1) reaction atmosphere contains too much O₂
- (2) catalyst has decomposed

Solutions:

- (1) Check for leaks in the sealed vials. If the sealed vials are not capped tightly, recap with a Teflon sealed cap and Parafilm over the cap and joint. Do not reuse Teflon seals as repeated punctures can compromise the integrity of the seal. Ensure that both the headspace of the protein and the buffer solution has been degassed thoroughly with argon. Argon is preferred over dinitrogen.
- (2) The catalyst should be stored as a frozen solution (as provided) in potassium phosphate buffer (0.1 M, pH 8.0) at -20 °C or below. Catalyst decomposition could be caused by improper storage of C/N transferase, degradation over time, or repeated freeze-thaw cycles. The catalyst is stable over at least 6 freeze-thaw cycles without any loss of activity. However, storage of the catalyst at room temperature for 12h will decrease the activity of the enzyme by up to 50%. To test for catalyst decomposition, perform a positive control with PRVV-001, styrene and EDA.

Problem: Substrate decomposition

Possible causes:

- (1) shelf age or photolysis of the carbene or nitrene precursor (e.g. EDA or tosyl azide)
- (2) decomposition of sodium dithionite

Solutions:

- (1) EDA should be refrigerated and protected from ambient light. The compound is usually sold as a solution in dichloromethane or toluene and is bright yellow in color. Samples that have decomposed will appear colorless.
- (2) Sodium dithionite is a white powder that should be odorless. If clumping or a strong odor of rotten egg is perceived, discard and use a fresh sample for reaction. Additionally, sodium dithionite solutions must be made immediately prior to use or kept under a rigorously anaerobic environment, as sodium dithionite undergoes air oxidation over time.

Problem: increased side product formation

Possible causes: order of addition

Solutions: The olefin partner should be added to the protein solution prior to the addition of ethyl diazoacetate. Ethyl diazoacetate will form diethyl maleate over time in the absence of a suitable olefin partner.

7. Recommended literatureSynthesis of cyclopropanes:

Wang, Z.J., Renata, H., Peck, N.E., Farwell, C.C., Coelho, P.S. & Arnold, F.H., Improved Cyclopropanation Activity of Histidine-Ligated Cytochrome P450 Enables the Enantioselective Formal Synthesis of Levomilnacipran. *Angewandte Chemie* **126**, 6928-6931 (2014).

Coelho, P.S., Wang, Z.J., Ener, M.E., Baril, S.A., Kannan, A., Arnold, F.H. & Brustad, E.M., A serine-substituted P450 catalyzes highly efficient carbene transfer to olefins in vivo. *Nature Chemical Biology* **9**, 485-487 (2013).

Coelho, P.S., Brustad, E.M., Kannan, A. & Arnold, F.H., Olefin Cyclopropanation via Carbene Transfer Catalyzed by Engineered Cytochrome P450 Enzymes. *Science (New York, N.Y.)* **339**, 307-310 (2013).

Synthesis of substituted amines:

Wang, Z.J., Peck, N.E., Renata, H. & Arnold, F.H., Cytochrome P450-Catalyzed Insertion of Carbenoids into N-H Bonds. *Chemical science (Royal Society of Chemistry : 2010)* **5**, 598-601 (2014).

Synthesis of substituted benzosultams:

McIntosh J. A., Coelho, P.S., Farwell, C.C., Wang, Z.J., Lewis, J.C., Brown, T.R. & Arnold, F.H., Enantioselective intramolecular C-H amination catalyzed by engineered cytochrome p450 enzymes in vitro and in vivo. *Angewandte Chemie (Int. Ed. in English)* **52**, 9309-9312 (2013).

Synthesis of sulfimides:

Farwell, C.C., McIntosh, J.A., Hyster, T.K., Wang, Z.J. & Arnold, F.H., Enantioselective Imidation of Sulfides via Enzyme-Catalyzed Intermolecular Nitrogen-Atom Transfer *J. Am. Chem. Soc.*, **136**, 8766-8771 (2014).

BIOCATALYSTS KITS Coming Soon.....**New Biocatalyst Kits Coming Soon.....**

Description	Strem Catalog #	CAS#	Color and form	Stability	(Approx.) Density	Product Use
NovoCor® AD L	06-3100	9001-62-1	brown liq.	Store at 0-25° C	1.17	Lipase that hydrolyzes ester bonds in glycerides. Declared activity 6000 LU/g.
Lipozyme® CALB L	06-3105	9001-62-1	yellow to light-brown liq.	Store at 0-10° C	1.20	Lipase that hydrolyzes ester bonds in glycerides. Declared activity 5000 LU/g.
Alcalase® 2.4L FG	06-3110	9014-01-1	brown liq.	Store at 0-10° C	1.17	Serine endoprotease that hydrolyzes internal peptide bonds. Declared activity 2.4 AU-A/g.
Alcalase® 2.5 L	06-3112	9014-01-1	amber liq., semi-transparent	Store at 0-25° C		Serine endoprotease that hydrolyzes internal peptide bonds. Declared activity 2.5 AU-A/g.
Esperase® 8.0 L	06-3115	9014-01-1	amber liq., semi-transparent	Store at 0-25° C		Serine endoprotease that hydrolyzes internal peptide bonds. Declared activity 8KNPU-E/g.
Palatase® 20000L	06-3118	9001-62-1	brown liq.	Store at 0-10° C		Lipase that hydrolyzes ester bonds in glycerides. Declared activity 20000 LU-MM/g.
Novozym® 40086	06-3120	9001-62-1	brown immobilized granulate	Store at 0-10° C	0.33	Lipase that hydrolyzes ester bonds in glycerides. Declared activity 275 IUN/g.
Novozym® 435	06-3123	9001-62-1	off-white immobilized granulate	Store at 0-25° C	0.40	Lipase that hydrolyzes ester bonds in glycerides. Declared activity 10000 PLU/g.
Resinase® HT	06-3125	9001-62-1	yellow liq.	Store at 0-25° C	1.05	Lipase that hydrolyzes ester bonds in glycerides. Declared activity 50 KLU/g.
Novozym 51032	06-3135	9001-62-1	yellow to light brown liq.	Store at 0-25° C		Lipase that hydrolyzes ester bonds in glycerides. Declared activity 15 KLU/g. (Product may be hazy and contain slight precipitate. This does not affect enzyme activity or performance.)
Savinase® 12 T	06-3137	9014-01-1	off-white granulate	Store at 0-25° C	1.0 - 1.3	Serine endoprotease that hydrolyzes internal peptide bonds. Declared activity 12 KNPU-S/g.
Lipozyme® TL 100 L	06-3140	9001-62-1	yellow liq.	Store at 0-10° C	1.05	Lipase that hydrolyzes ester bonds in glycerides. Declared activity 100 KLU/g.
Savinase® 16 L	06-3150	9014-01-1	amber liq., semi-transparent	Store at 0-25° C		Serine endoprotease that hydrolyzes internal peptide bonds. Declared activity 16 KNPU-S/g.
Lipozym® TL IM	06-3155	9001-62-1	off-white immobilized granulate	Store at 0-10° C	0.40	Lipase that hydrolyzes ester bonds in glycerides. Declared activity 250 IUN/g.
Neutrase® 0.8L	06-3160	9080-56-2	brown liq.	Store at 0-10° C	1.26	Metallo endoprotease that hydrolyzes internal peptide bonds. Declared activity 0.8 AU/g.
rTrypsin™	06-3165	9002-07-7	brown granulate	Store at 0-25° C		Serine endoprotease that hydrolyzes internal peptide bonds. Declared activity 800 USP/mg.

Use: Industrial grade enzymes produced by Novozymes.

GOLD (Compounds)

79-0245

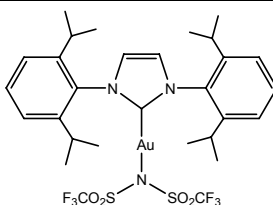
NEW→

[1,3-Bis(2,6-di-*i*-propylphenyl) 2H-imidazol-2-ylidene][bis(trifluoromethanesulfonyl)imide]gold(I), min. 95%

[951776-24-2]

C₂₉H₃₆AuF₆O₄S₂; FW: 824.69;

white to pale yellow solid

air sensitive

100mg

500mg

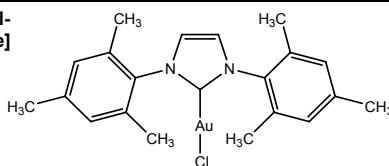
79-1200

NEW→

Chloro[1,3-bis(2,4,6-trimethylphenyl)2H-imidazol-2-ylidene] gold(I), 98% [852445-81-9]

C₂₁H₂₄AuClN₂; FW: 536.85;

white powd.

air sensitive

100mg

500mg

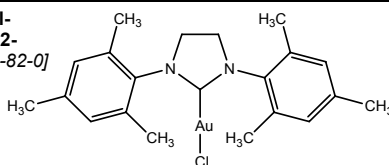
79-1205

NEW→

Chloro[1,3-bis(2,4,6-trimethylphenyl)-4,5-dihydroimidazol-2-ylidene]gold(I), 98% [852445-82-0]

C₂₁H₂₆AuClN₂; FW: 538.86;

white powd.

air sensitive

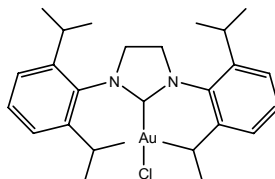
100mg

500mg

79-1210

NEW→

Chloro[1,3-bis[2,6-bis(1-methylethyl)phenyl]-4,5-dihydroimidazol-2-ylidene]gold(I), 98% [852445-84-2]

C₂₇H₃₈AuClN₂; FW: 623.02; white powd.*air sensitive*

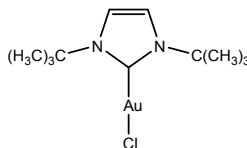
100mg

500mg

79-1215

NEW→

Chloro[1,3-bis(1,1'-dimethylethyl)2H-imidazol-2-ylidene]gold(I), 98% [839722-07-5]

C₁₁H₂₀AuClN₂; FW: 412.71; white powd.*air sensitive*

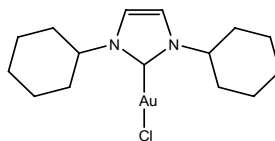
100mg

500mg

79-1220

NEW→

Chloro[1,3-bis(cyclohexyl)2H-imidazol-2-ylidene]gold(I), 98% [852445-87-5]

C₁₅H₂₄AuClN₂; FW: 464.78; white powd.*air sensitive*

100mg

500mg

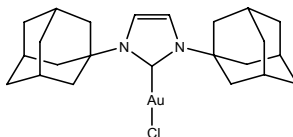
79-1225

NEW→

Chloro[1,3-bis(adamantyl)2H-imidazol-2-ylidene]gold(I), 98% [852445-8-6]

C₂₃H₃₂AuClN₂; FW: 568.93;

white powd.

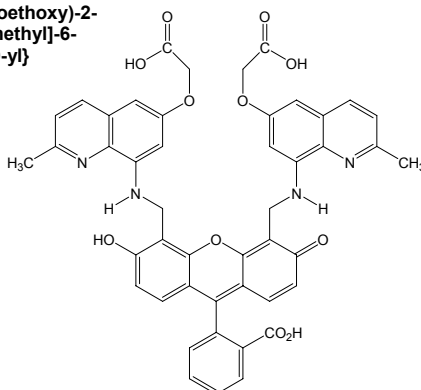
air sensitive

100mg

500mg

NITRIC OXIDE SENSOR (INTRACELLULAR) KIT ("NO-ON") (FL2A)
(CELL-TRAPPABLE NO FLUORESCENT PROBE)
96-0397 Nitric Oxide Sensor (Intracellular) Kit ("NO-ON") (FL2A)
NEW → (Cell-trappable NO fluorescent probe)

Contains the following:

Active Ingredient:
2-[4,5-Bis[[6-(2-ethoxy-2-oxoethoxy)-2-methylquinolin-8-ylamino)methyl]-6-hydroxy-3-oxo-3H-xanthen-9-yl]benzoic acid FL2A
Catalog number - 07-0287

Introduction:

The copper complex of **FL2A** is a novel, cell-trappable fluorescent NO probe, that allows direct imaging of nitric oxide produced in living cells through fluorescence turn on. The **FL2A** ligand is trapped in the cell. A solution of the copper (II) complex of **FL2A** can be readily prepared using this kit.

For additional information, consult the following references:

1. *Inorg. Chem.*, **2010**, 49, 7464.
2. *PNAS*, **2010**, 107, 8525.

Contents:

 Ligand **FL2A**: 5 x 0.5mg

Dimethylsulfoxide (ACS spectrophotometric grade): 5 x 1.0ml

Copper (II) chloride (1.0 mM solution in water): 5 x 1.0ml

SDS:

The Material Safety Data Sheets for the three products contained in this kit can be downloaded from the Strem Chemicals Web Site at www.strem.com. Locate the SDS using the following catalog numbers:

FL2A: 07-0291

Dimethylsulfoxide (ACS spectrophotometric grade): 97-4940

Copper (II) chloride as a 1.0 mM solution in water: 97-3060

Storage conditions:

The kit should be stored at -20°C and protected from light.

Preparation of the active copper complex of FL2A:
Step I

Allow the kit to warm to room temperature. Add 589 microliters of DMSO to a 0.5mg vial of **FL2A** (resulting concentration - 1.0 mM). The **FL2A** is readily soluble in the DMSO. The solution can be partitioned into aliquots of 40-300 µL as required. These solutions must be stored in the freezer at <-20°C. The DMSO solution of **FL2A** is stable for three months at -80°C. It is advisable to check the extinction coefficient of the solution before preparing the copper complex. (log ε(499 nm) = 4.66)

Step II

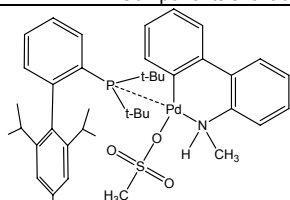
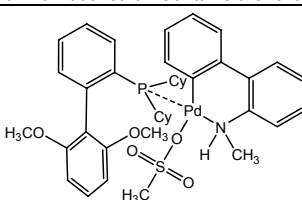
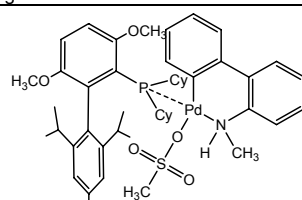
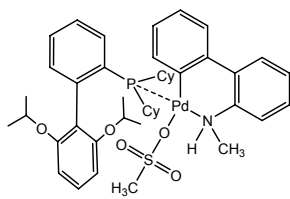
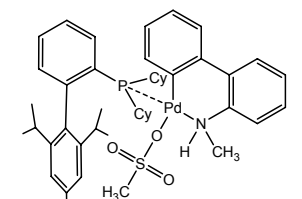
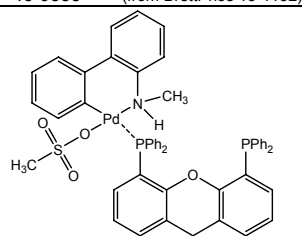
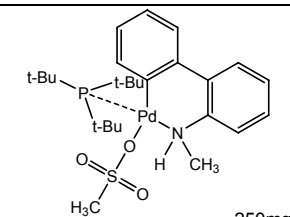
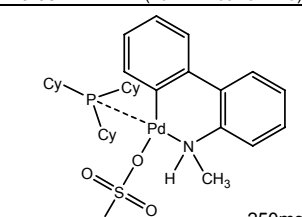
A Cu**FL2A** solution should be freshly prepared by adding 1:2 **FL2A** solution (1.0 mM) to the copper (II) solution (1.0 mM) at room temperature.

Note: The prepared DMSO/water stock solution of Cu**FL2A** solution [log ε(495 nm) = 4.19] can be kept at room temperature, but should be protected from light. The solution can be diluted with media to provide the concentration required for cell sensing experiments. When the extinction coefficient of the red solution of Cu**FL2A** diminishes by 20% of the original value, the solution should be discarded. Do not use the solution after 1 hour, and do not freeze the solution.

07-0287	2-[4,5-Bis[[6-(2-ethoxy-2-oxohydroxy)-2-methylquinolin-8-ylamino)methyl]-6-hydroxy-3-oxo-3H-xanthen-9-yl]benzoic acid FL2A [1239877-07-6]	0.5mg	See page 60
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Catalyst & Organocatalyst Kits - APEIRON METATHESIS CATALYST KIT**96-0400 Apeiron Ruthenium Metathesis Catalyst Kit****NEW→** See (page 11).**BUCHWALD PALLADACYCLE PRECATALYST KIT 4****(METHANESULFONATO-2'-METHYLAMINO-1,1'-BIPHENYL-2-YL- PALLADACYCLES GEN. 4)****96-5512 Buchwald Palladacycle Precatalyst Kit 4****NEW→** (Methanesulfonato-2'-methylamino-1,1'-biphenyl-2-yl- Palladacycles Gen. 4)

Components available for individual sale. Contains the following:

**46-0330** (from t-BuXphos 15-1052) **250mg****46-0380** (from SPhos 15-1143) **250mg****46-0333** (from BrettPhos 15-1152) **250mg****46-0395** (from RuPhos 15-1146) **250mg****46-0327** (from XPhos 15-1149) **250mg****46-0388** (from Xantphos 15-1242) **250mg****46-0385** (from P(t-Bu)3 15-5810) **250mg****46-0379** (from PCy3 15-6150) **250mg**

Note: Patents:
PCT/US2013/030779,
US Serial No. 13/799620.

46-0327	Methanesulfonato(2-dicyclohexylphosphino-2',4',6'-tri- <i>i</i> -propyl-1,1'-biphenyl)(2'-methylamino-1,1'-biphenyl-2-yl)palladium(II), min. 98% [XPhos Palladacycle Gen. 4] [1599466-81-5]	See page 49
46-0330	Methanesulfonato(2-di- <i>t</i> -butylphosphino-2',4',6'-tri- <i>i</i> -propyl-1,1'-biphenyl)(2'-methylamino-1,1'-biphenyl-2-yl)palladium(II) dichloromethane adduct, min. 98% [t-BuXphos Palladacycle Gen. 4] [1599466-89-3]	See page 48
46-0333	Methanesulfonato(2-dicyclohexylphosphino-3,6-dimethoxy-2',4',6'-tri- <i>i</i> -propyl-1,1'-biphenyl)(2'-methylamino-1,1'-biphenyl-2-yl)palladium(II), min. 98% [BrettPhos Palladacycle Gen. 4] [1599466-83-7]	See page 49
46-0379	Methanesulfonato(tricyclohexylphosphino)(2'-methylamino-1,1'-biphenyl-2-yl)palladium(II), 98% [PCy3 Palladacycle Gen. 4]	See page 50
46-0380	Methanesulfonato(2-dicyclohexylphosphino-2',6'-dimethoxy-1,1'-biphenyl)(2'-methylamino-1,1'-biphenyl-2-yl)palladium(II) dichloromethane adduct, min. 98% [SPhos Palladacycle Gen. 4] [1599466-87-1]	See page 49
46-0385	Methanesulfonato(tri- <i>t</i> -butylphosphino)(2'-methylamino-1,1'-biphenyl-2-yl)palladium(II), 98% [P(t-Bu)3 Palladacycle Gen. 4] [1621274-11-0]	See page 50
46-0388	Methanesulfonato[9,9-dimethyl-4,5-bis(diphenylphosphino)xanthene](2'-methylamino-1,1'-biphenyl-2-yl)palladium(II), 98% [Xantphos Palladacycle Gen. 4]	See page 50
46-0395	Methanesulfonato(2-dicyclohexylphosphino-2',6'-di- <i>i</i> -propoxy-1,1'-biphenyl)(2'-methylamino-1,1'-biphenyl-2-yl)palladium(II), min. 98% [RuPhos Palladacycle Gen. 4] [1599466-85-9]	See page 49

Note: Patents: PCT/US2013/030779, US Serial No. 13/799620.

CHROMIUM (Compounds)

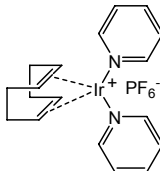
24-0183 **Chromium carbonyl, 98+% [13007-92-6]** 5g
NEW→ $\text{Cr}(\text{CO})_6$; FW: 220.06; white to off-white solid. 25g
 HAZ 100g

Technical Note:

1. See 24-0180 (Visit strem.com).

IRIDIUM (Compounds)

77-0440 **Bis(pyridine)(1,5-cyclooctadiene)iridium(I)** 250mg
NEW→ **hexafluorophosphate, 99% [56678-60-5]** 1g
 $(\text{C}_5\text{H}_5\text{N})_2(\text{C}_8\text{H}_{12})\text{Ir}^+\text{PF}_6^-$; FW: 603.56;
 orange powdr.
air sensitive



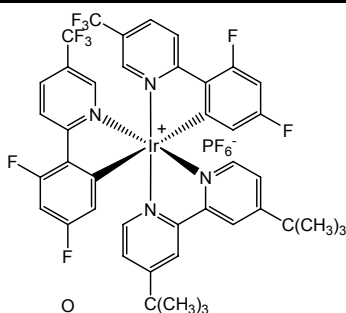
Technical Notes:

1. This complex is used in the isomerization of primary allylic alcohols. (Ref. 1)
2. The catalyst is used for ortho-directed hydrogen-isotope exchange. (Ref. 2)

References:

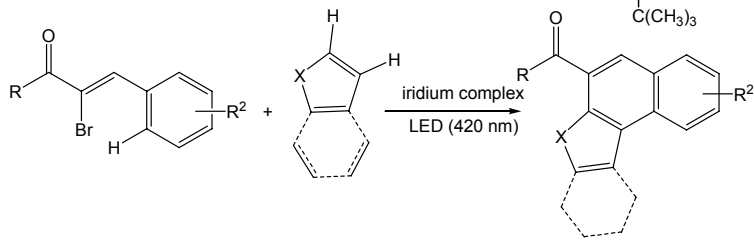
1. *Eur. J. Inorg. Chem.*, **2012**, 3320.
2. *J. Labelled Compd. Rad.*, **2010**, 53, 695.

77-0425 **(4,4'-Di-t-butyl-2,2'-bipyridine)bis** 50mg
NEW→ **[3,5-difluoro-2-[5-trifluoromethyl-2-pyridinyl-kN)phenyl-kC]iridium(III)** 250mg
hexafluorophosphate, 99% [870987-63-6]
 $[\text{Ir}(\text{C}_{18}\text{H}_{24}\text{N}_2)(\text{C}_{12}\text{H}_5\text{F}_5\text{N})_2]^+\text{PF}_6^-$; FW: 1121.91;
 yellow xtl..

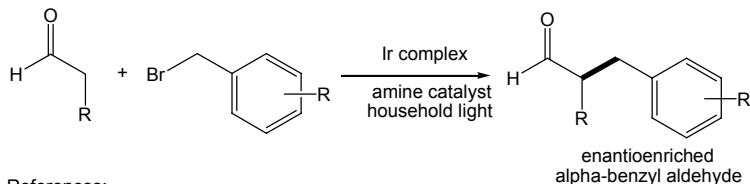


Technical Notes:

1. Visible light photoredox-catalyzed cascade cyclizations of α -bromochalcones or α -bromocinnamates with heteroarenes.
2. Enantioselective α -benzylation of aldehydes via photoredox organocatalysis.



Tech. Note (1)
Ref. (1)



Tech. Note (2)
Ref. (2)

References:

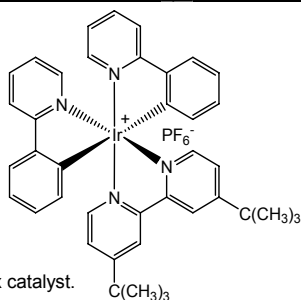
1. *Adv. Synth. Cat.*, **2014**, 356, 557.
2. *J. Amer. Chem. Soc.*, **2010**, 132, 13600.

IRIDIUM (Compounds)

77-0410

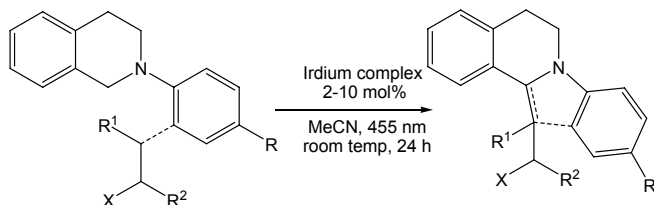
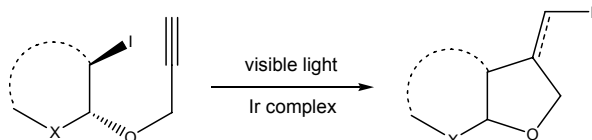
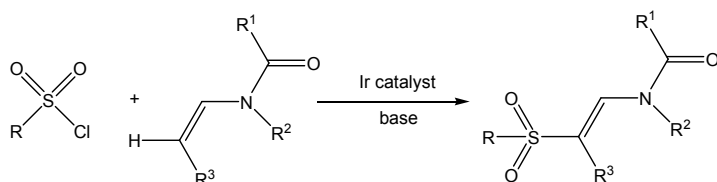
NEW→

(4,4'-Di-*t*-butyl-2,2'-bipyridine)bis[2-(2-pyridinyl-*k*N)phenyl-*k*C]iridium(III) hexafluorophosphate, 99% [676525-77-2]
 $[\text{Ir}(\text{C}_{18}\text{H}_{24}\text{N}_2)(\text{C}_{11}\text{H}_8\text{N})_2]^+\text{PF}_6^-$; FW: 913.95; yellow xtl.

100mg
500mg

Technical Notes:

1. Generation and addition of N-aryltetrahydroisoquinoline-derived α -amino radicals to Michael acceptors.
2. Visible light photoredox atom transfer – the Ueno-Stork reaction.
3. Synthesis of β -amidovinyl sulfones via visible-light photoredox catalysis.
4. This iridium complex has numerous uses as a photoredox catalyst.

Tech. Note (1)
Ref. (1)Tech. Note (2)
Ref. (2)Tech. Note (3)
Ref. (3)

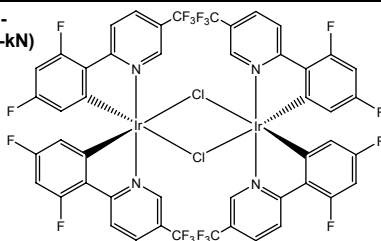
References:

1. *Org. Lett.*, **2012**, 14, 672.
2. *Org. Biomol. Chem.*, **2013**, 11, 7088.
3. *Adv. Synth. Cat.*, **2013**, 355, 809.

77-0468

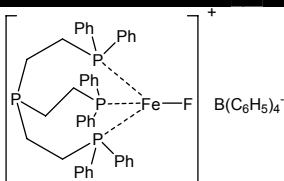
NEW→

Di- μ -chlorotetrakis[3,5-difluoro-2-[5-trifluoromethyl-2-pyridinyl-*k*N)phenyl-*k*C]diiridium(III), 99% [870987-64-7]
 $\text{C}_{48}\text{H}_{20}\text{Cl}_2\text{F}_{20}\text{OIr}_2\text{N}_4$;
 FW: 1488.01; yellow xtl.

50mg
250mg

IRON (Compounds)**26-3955****NEW→**

Tris{[2-(diphenylphosphino)ethyl]phosphine}(fluoro)iron(II) tetraphenylborate, min. 98%
 [1318882-54-0]
 $C_{66}H_{62}FeBFP_4$; FW: 1064.75; purple solid



100mg
500mg

GOLD (Compounds)**79-0345****NEW→**

Chloro(dimethylsulfide)gold(I), min. 97% [29892-37-3]
 $(CH_3)_2SAuCl$; FW: 294.55; white to off-white solid
light sensitive, (store cold)

250mg
1g

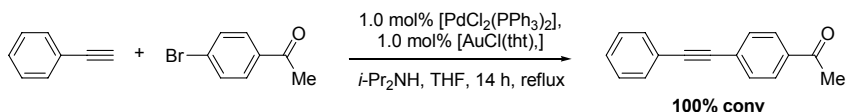
79-1122**NEW→**

Chloro(tetrahydrothiophene)gold(I), min. 98% [39929-21-0]
 $(C_4H_8S)AuCl$; FW: 320.59; white to off-white powdr.
air sensitive, heat sensitive, light sensitive, (store cold)

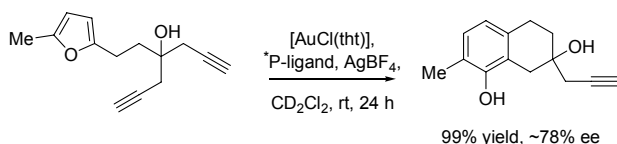
100mg
500mg

Technical Notes:

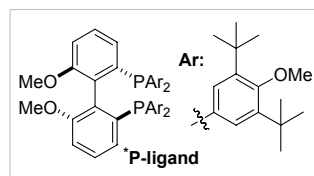
1. Employed as co-catalyst in Pd-catalyzed alkylation.
2. Au-catalyzed phenol synthesis.

**100% conv**

Tech. Note (1)
Ref. (1)



99% yield, ~78% ee



Tech. Note (2)
Ref. (2)

References:

1. *Catalysis Today*, **2007**, 122, 403.
2. *Chem. Eur. J.*, **2009**, 15, 13318.

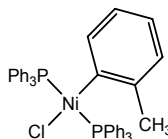
IRIDIUM (Compounds)**77-3010****NEW→**

Iridium(III) chloride, hydrate (99.99%+-Ir) PURATREM
[free of Ir(IV) by electrochemical analysis] [14996-61-3]
 $IrCl_3 \cdot xH_2O$; FW: 298.58; black xtl.
hygroscopic

250mg
1g
5g

NICKEL (Compounds)**28-0096****NEW→**

Bis(triphenylphosphino)(2-methylphenyl) chloronickel(II), 99% [27057-09-6]
 $C_{43}H_{37}ClNiP_2$; FW: 709.85; yellow powdr.



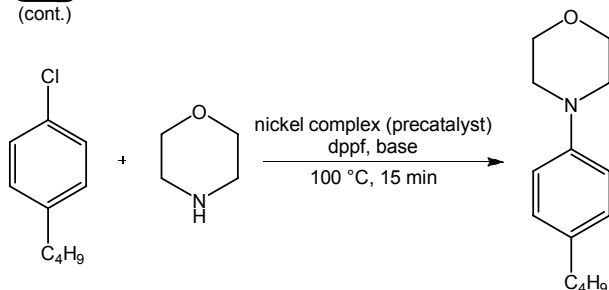
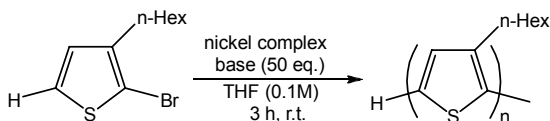
250mg
1g

Technical Notes:

1. This complex is used as an air-stable nickel precatalyst for the amination of aryl chlorides, sulfamates, mesylates, and triflates.
2. This nickel precatalyst is used for the polymerization of halothiophenes.

NICKEL (Compounds)**28-0096** Bis(triphenylphosphino)(2-methylphenyl)chloronickel(II), 99% [27057-09-6]**NEW→**

(cont.)

**Tech. Note (1)**
Ref. (1)**Tech. Note (2)**
Ref. (2)

References:

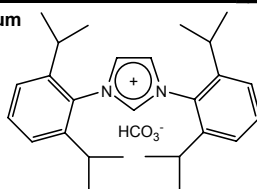
1. *Org. Lett.*, **2014**, 16, 220.
2. *Organometallics*, **2012**, 31, 2263.

NITROGEN (Compounds)**07-0484** 1,3-Bis(2,6-di-*i*-propylphenyl)imidazolium bicarbonate, min. 97% IPrH. HCO_3^- 500mg
2g

[1663476-15-0]

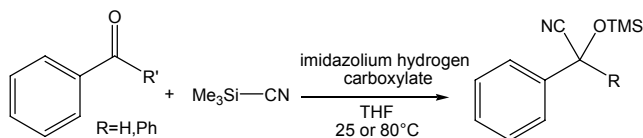
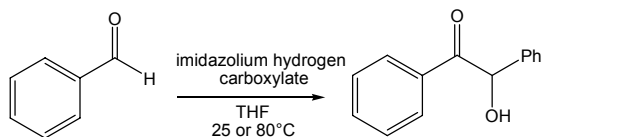
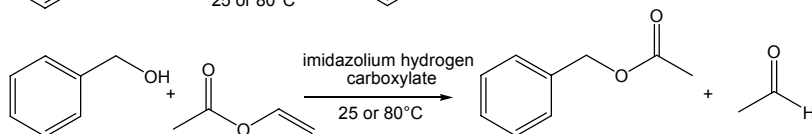
 $[\text{C}_{27}\text{H}_{37}\text{N}_2]^+\text{HCO}_3^-$; FW: 450.61;
white to off-white powdr.

hygroscopic



Technical Notes:

1. Catalyst used for the cyanosilylation of benzaldehyde or benzophenone.
2. Catalyst used in the benzoin condensation reaction.
3. Catalyst used to effect the transesterification between benzyl alcohol and vinyl acetate.

**Tech. Note (1)**
Ref. (1)**Tech. Note (2)**
Ref. (1)**Tech. Note (3)**
Ref. (1)

References:

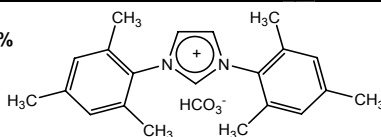
1. *J. Org. Chem.*, **2012**, 77, 10135..
2. *Catal. Sci. Technol.*, **2014**, 4, 2466.

NITROGEN (Compounds)

07-4033

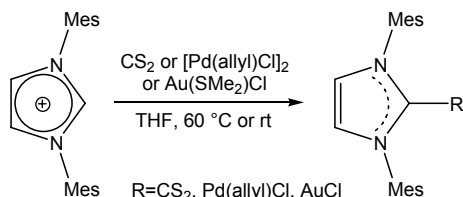
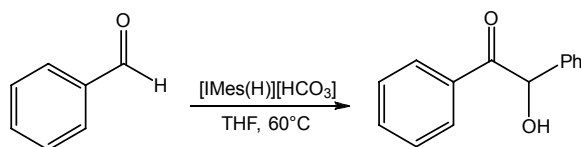
NEW→

1,3-Bis(2,4,6-trimethylphenyl)imidazolium bicarbonate, min. 97%
IMesH.HCO₃ [1372124-93-0]
 [C₂₁H₂₅N₂]⁺HCO₃⁻; FW: 366.45;
 white to yellow-orange powd.
moisture sensitive

500mg
2g

Technical Notes:

1. This compound is used as a source of NHC's and can be transferred to transition metals.
2. This catalyst is used in the benzoin condensation reaction.

Tech. Note (1)
Ref. (1)Tech. Note (2)
Ref. (1, 2)

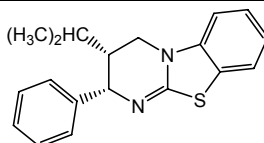
References:

1. *J. Am. Chem. Soc.*, **2012**, 134, 6776.
2. *J. Org. Chem.*, **2012**, 77, 10135.

07-0496

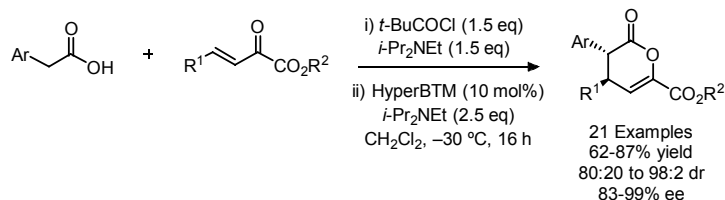
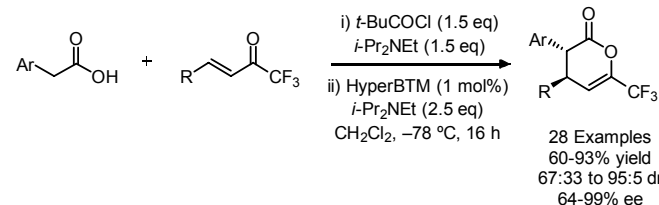
NEW→

(2R,3S)-(-)-3,4-Dihydro-3-(i-propyl)-2-phenyl-2H-pyrimido[2,1-b]benzothiazole, min. 98% HyperBTM
[1203507-02-1]
 C₁₉H₂₀N₂S; FW: 308.44;
 white powd.; [α]_D +288.4°

100mg
500mg

Technical Notes:

1. Isothiourea-mediated intermolecular Michael addition-lactonisation.
2. Isothiourea-mediated, asymmetric, Michael-lactonisation of CF₃ – enones
3. α-Functionalisation of 3-alkenoic acids
4. Isothiourea-catalyzed α-amination of carboxylic acids.
5. Isothiourea-catalyzed O- to C- carboxyl transfer of furanyl carbonates
6. Isothiourea-catalyzed kinetic resolution of secondary alcohols
7. Isothiourea-catalyzed α-amination of carboxylic acids with N-aryl-N-aryldiazene

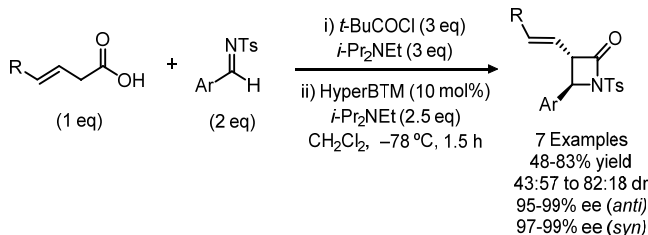
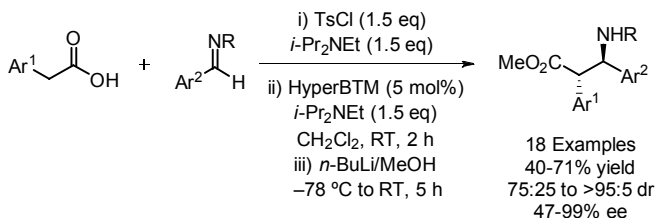
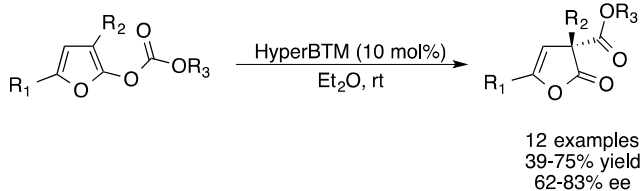
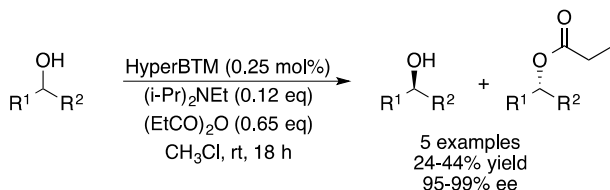
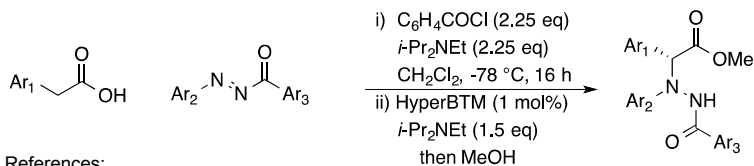
Tech. Note (1)
Ref. (1)Tech. Note (2)
Ref. (2)

NITROGEN (Compounds)

07-0496

NEW→

(cont.)

(2R,3S)-(-)-3,4-Dihydro-3-(*i*-propyl)-2-phenyl-2H-pyrimido[2,1-*b*]benzothiazole, min. 98% HyperBTM [1203507-02-1]Tech. Note (3)
Ref. (3)Tech. Note (4)
Ref. (4)Tech. Note (5)
Ref. (5)Tech. Note (6)
Ref. (6)Tech. Note (7)
Ref. (7)

References:

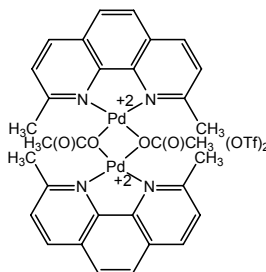
1. *J. Am. Chem. Soc.*, **2011**, 133, 2714.
2. *Org. Biomol. Chem.*, **2014**, 12, 624.
3. *J. Org. Chem.*, **2014**, 79, 1640.
4. *J. Org. Chem.*, **2014**, 79, 1626.
5. *Synthesis*, **2011**, 12, 1865.
6. *Org. Biomol. Chem.*, **2011**, 9, 559.
7. *Chem. Sci.*, **2012**, 3, 2088.

PALLADIUM (Compounds)**96-5512****NEW→**

Buchwald Palladacycle Precatalyst Kit 4
(Methanesulfonato-2'-methylamino-1,1'-biphenyl-2-yl)- Palladacycles Gen. 4)
 See (page 37)

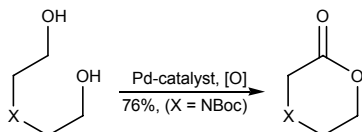
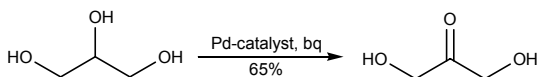
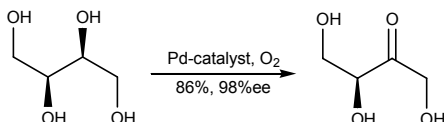
46-0970**NEW→**

Acetato(2,9-dimethyl-1,10-phenanthroline)palladium(II) dimer bis(trifluoromethanesulfonate), 99%
[959698-19-2]
 $C_{34}H_{30}F_6N_4O_{10}Pd_2S_2$; FW: 1045.59;
 dark orange powdr.

100mg
500mg

Technical Note:

1. This dimeric palladium complex is used in the chemoselective oxidation of polyols.



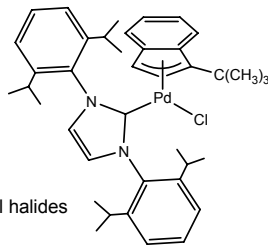
X = O, NBoc
 [O] = air, O₂, benzoquinone

Reference:

1. *J. Am. Chem. Soc.*, **2013**, 135, 7593.

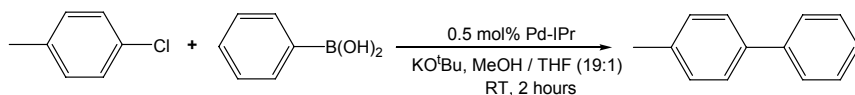
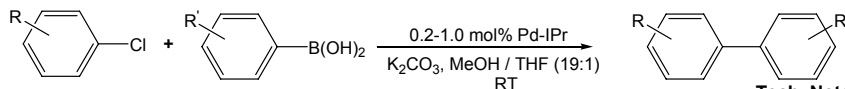
46-0815**NEW→**

Chloro(1-*t*-butylindenyl)[1,3-bis(2,6-di-*i*-propylphenyl)imidazol-2-yl] palladium(II), 98%
 $C_{40}H_{51}ClN_2Pd$; FW: 701.72; orange powdr.

100mg
500mg

Technical Note:

1. Catalyst used in the Suzuki cross-coupling of aryl halides and aryl boronic acids.

**Tech. Note (1)****Tech. Note (1)**

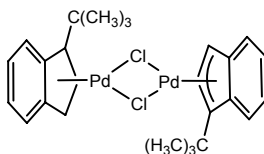
PALLADIUM (Compounds)

46-0868

NEW→

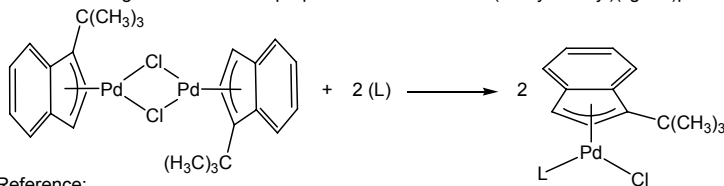
Chloro(1-t-butylindenyl) palladium(II) dimer, 98%
 $C_{26}H_{30}Cl_2Pd_2$; FW: 626.26;
 brown powdr.

100mg
 500mg



Technical Note:

- Starting material used to prepare monomeric chloro(t-butylindenyl)(ligand)palladium complexes.



Reference:

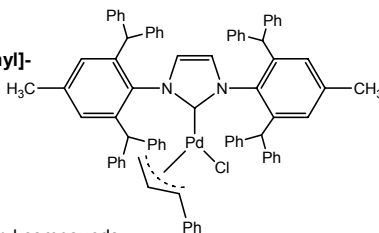
- ACS Catal., 2015, 5, 3680.

46-0298

NEW→

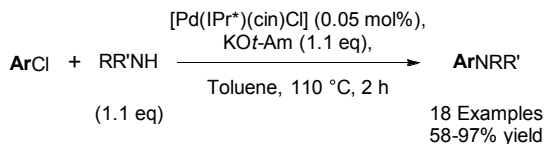
Chloro[(1,2,3-η)-1-phenyl-2-propen-1-yl]-[1,3-bis[2,6-bis(diphenylmethyl)-4-methylphenyl]-2H-imidazol-2-ylidene] palladium(II), min. 97%
 [1380314-24-8]
 $C_{78}H_{65}ClN_2Pd$; FW: 1172.24;
 yellow powdr.

100mg
 500mg

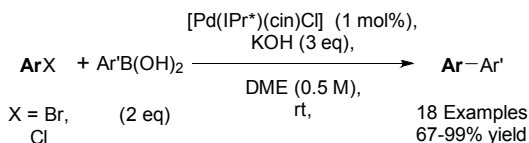


Technical Notes:

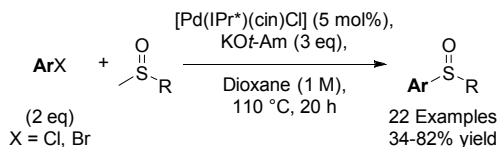
- Buchwald-Hartwig cross-coupling of aryl compounds.
- Preparation of tetra-ortho-substituted biaryls by Suzuki-Miyaura cross-coupling.
- Direct S-arylation of unactivated arylsulfonides.



Tech. Note (1)
 Ref. (1)



Tech. Note (2)
 Ref. (2)



Tech. Note (3)
 Ref. (3)

R = phenyl, tolyl, naphthyl, anisyl.

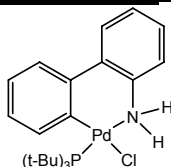
References:

- (a) For tertiary amines: *Adv. Synth. Catal.*, 2012, 354, 1897.
 (b) For secondary amines: *RSC Advances*, 2013, 3, 3840.
- Chem. Eur. J.*, 2012, 18, 4517.
- ACS Catal., 2013, 3, 2190.

PALLADIUM (Compounds)

46-0028 **Chloro(tri-*t*-butylphosphine)**
(2'-amino-1,1'-biphenyl-2-yl)palladium(II),
min. 98% [1375325-71-5]
 $C_{24}H_{37}ClNPPd$; FW: 512.40; yellow powdr.;
 m.p. 158-160°

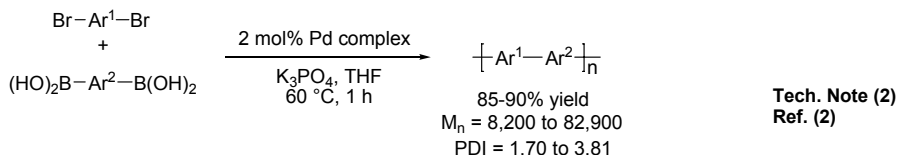
NEW→



250mg
1g
5g

Technical Notes:

1. Palladium catalyst used in the coupling reaction of aryl halides with polyfluoroarenes.
2. Palladium catalyst used in the Suzuki-Miyaura cross-coupling polymerization of aryl dibromides with arylboronic acids.

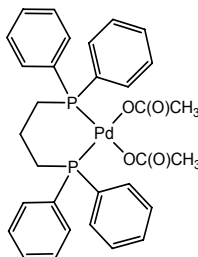


References:

1. *Eur. J. Org. Chem.*, **2014**, 1327.
2. *ACS Macro. Lett.*, **2013**, 2, 10.
3. *Chem. Sci.*, **2013**, 4, 916.

46-0257 **Diacetato[1,3-bis(diphenylphosphino)**
propane]palladium(II), 99% [149796-59-8]
 $C_{31}H_{32}O_4P_2Pd$; FW: 636.95; yellow-brown solid
 moisture sensitive

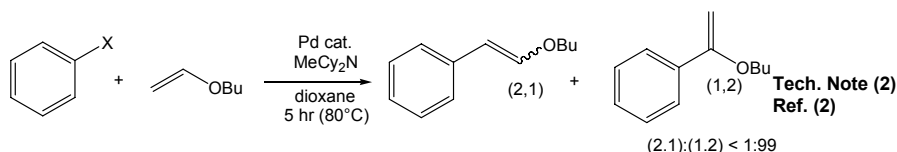
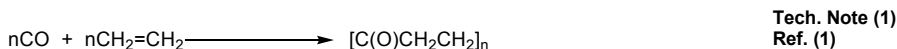
NEW→



250mg
1g

Technical Notes:

1. Catalyst used for the copolymerization of ethene with carbon monoxide.
2. Catalyst used in the Heck reactions of vinyl ethers.



References:

1. *Mod. Res. in Catal.*, **2013**, 2, 93.
2. *J. Am. Chem. Soc.*, **2010**, 132, 79.

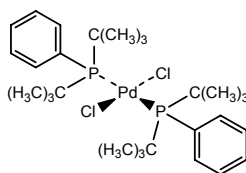
PALLADIUM (Compounds)

46-0420

NEW→

Dichlorobis(di-*t*-butylphenylphosphino)palladium(II), 99%
 [34409-44-4]

$C_{28}H_{46}Cl_2P_2Pd$; FW: 621.94;
 colorless to pale-yellow solid



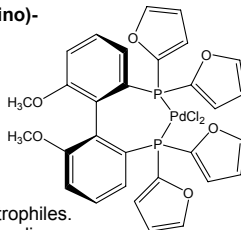
250mg
 1g

46-0188

NEW→

Dichloro[(*R*)-(+)-2,2'-bis(di-2-furanylphosphino)-6,6'-dimethoxy-1,1'-biphenyl]palladium(II)
 [1338245-54-7]

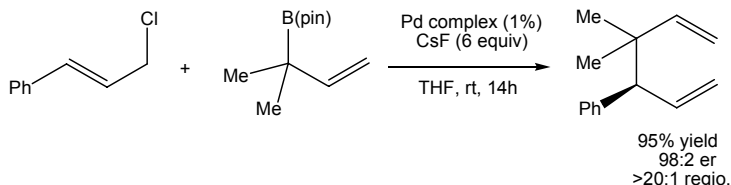
$C_{30}H_{24}Cl_2O_6P_2Pd$; FW: 719.78;
 pale yellow powdr.



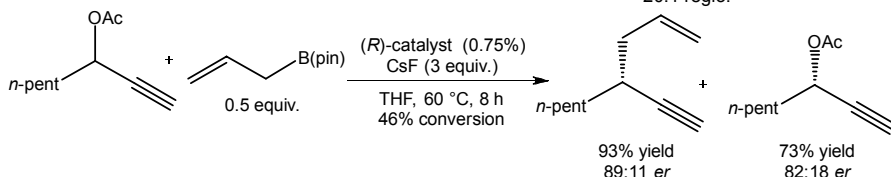
50mg
 250mg

Technical Notes:

1. This Palladium-complex is used for the asymmetric cross-coupling of allylboron reagents with allylic electrophiles.
2. The catalyst is used for the kinetic resolution of propargylic acetates to give enantioenriched 1,5-enynes.



Tech. Note (1)
Ref. (1)



Tech. Note (2)
Ref. (2)

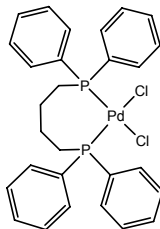
References:

1. *J. Am. Chem. Soc.*, **2014**, 136, 7092.
2. *Adv. Synth. Catal.*, **2013**, 355, 3413.

46-0468

NEW→

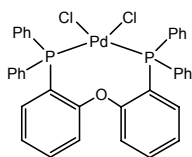
Dichloro[1,4-bis(diphenylphosphino)butane]palladium(II), 99% [29964-62-3]
 $C_{28}H_{28}Cl_2P_2Pd$; FW: 603.80; light-yellow powdr.



1g
 5g

PALLADIUM (Compounds)

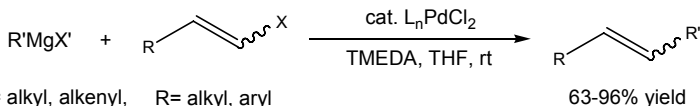
46-0463 **Dichloro[bis[2-(diphenylphosphino)phenyl]ether]palladium(II), 98% [205319-06-8]**
NEW→ $C_{36}H_{28}Cl_2OP_2Pd$; FW: 715.88; yellow powdr.



1g
5g

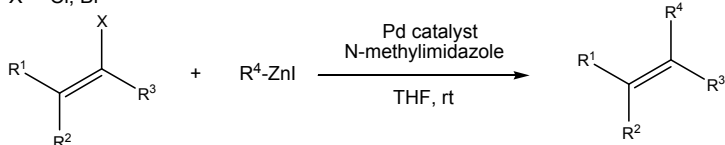
Technical Notes:

1. Stereoretentive palladium-catalyzed Kumada-Corriu couplings of alkenyl halides at room temperature.
2. Highly selective reactions of unbiased alkenyl halides: Negishi-Plus couplings.



R' = alkyl, alkenyl, alkenyl, aryl
 R = alkyl, aryl
 X = I, Br

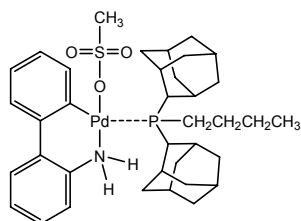
X' = Cl, Br



References:

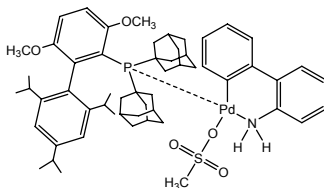
1. *Org. Lett.*, **2014**, 16, 4066.
2. *Org. Lett.*, **2011**, 13, 3822.

46-0278 **Methanesulfonato(diadamantyl-n-butylphosphino)-2'-amino-1,1'-biphenyl-2-yl)palladium(II), min. 95% [cataCXium® A Palladacycle Gen. 3]**
NEW→ $C_{37}H_{52}NO_3PPdS$; FW: 728.27; off-white powdr.
 Note: Patents: PCT/US2013/030779, US Serial No. 13/799620.



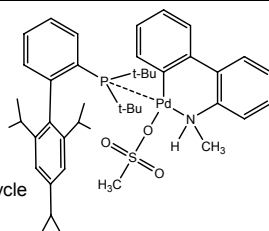
250mg
1g
5g

46-0480 **Methanesulfonato[2-(di-1-adamantylphosphino)-3,6-dimethoxy-2',4',6'-tri-i-propyl-1,1'-biphenyl](2'-amino-1,1'-biphenyl-2-yl)palladium(II), min. 98% [AdBrettPhos Palladacycle Gen. 3]**
NEW→ $C_{56}H_{74}NO_5PPdS$; FW: 1010.65; white to beige solid
 Note: Patents: PCT/US2013/030779, US Serial No. 13/799620



50mg
250mg

46-0330 **Methanesulfonato(2-di-t-butylphosphino-2',4',6'-tri-i-propyl-1,1'-biphenyl)(2'-methylamino-1,1'-biphenyl-2-yl)palladium(II) dichloromethane adduct, min. 98% [t-BuXphos Palladacycle Gen. 4]**
NEW→ $C_{43}H_{60}NO_3PPdS$; FW: 808.40; white powdr.
 Note: Patents: PCT/US2013/030779, US Serial No. 13/799620. Buchwald Palladacycle Precatalyst Kit 4 (Methanesulfonato-2'-methylamino-1,1'-biphenyl-2-yl-Palladacycles Gen. 4) component. See (page 37).



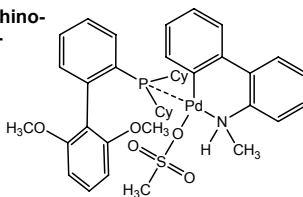
250mg
1g
5g

PALLADIUM (Compounds)

46-0380

NEW→

Methanesulfonato(2-dicyclohexylphosphino-2',6'-dimethoxy-1,1'-biphenyl)(2'-methylamino-1,1'-biphenyl-2-yl)palladium(II) dichloromethane adduct min. 98% [SPhos Palladacycle Gen. 4]
 [1599466-87-1]
 $C_{40}H_{50}NO_5PPdS$; FW: 794.29; white powd.
 Note: Patents: PCT/US2013/030779, US Serial No. 13/799620. Buchwald Palladacycle Precatalyst Kit 4 (Methanesulfonato-2'-methylamino-1,1'-biphenyl-2-yl- Palladacycles Gen. 4) component. See (page 37).

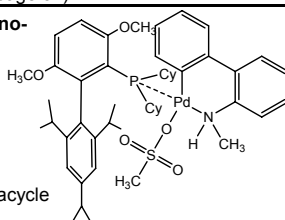


250mg
1g
5g

46-0333

NEW→

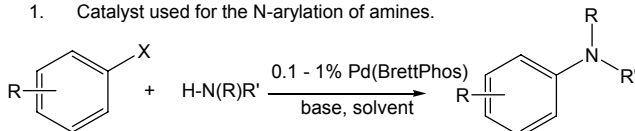
Methanesulfonato(2-dicyclohexylphosphino-3,6-dimethoxy-2',4',6'-tri-*i*-propyl-1,1'-biphenyl)(2'-methylamino-1,1'-biphenyl-2-yl)palladium(II), min. 98% [BrettPhos Palladacycle Gen. 4]
 [1599466-83-7]
 $C_{49}H_{68}NO_5PPdS$; FW: 920.53; white powd.
 Note: Patents: PCT/US2013/030779, US Serial No. 13/799620. Buchwald Palladacycle Precatalyst Kit 4 (Methanesulfonato-2'-methylamino-1,1'-biphenyl-2-yl- Palladacycles Gen. 4) component. See (page 37).



250mg
1g
5g

Technical Note:

1. Catalyst used for the N-arylation of amines.



Tech. Note (1)
Ref. (1)

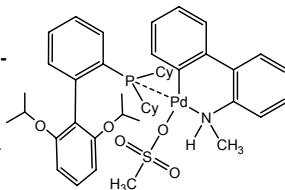
References:

1. *J. Org. Chem.*, **2014**, 79, 4161.
2. *Chem. Sci.*, **2013**, 4, 916.

46-0395

NEW→

Methanesulfonato(2-dicyclohexylphosphino-2',6'-di-*i*-propoxy-1,1'-biphenyl)(2'-methylamino-1,1'-biphenyl-2-yl)palladium(II), min. 98% [RuPhos Palladacycle Gen. 4]
 [1599466-85-9]
 $C_{44}H_{58}NO_5PPdS$; FW: 850.40; white powd.
 Note: Patents: PCT/US2013/030779, US Serial No. 13/799620. Buchwald Palladacycle Precatalyst Kit 4 (Methanesulfonato-2'-methylamino-1,1'-biphenyl-2-yl- Palladacycles Gen. 4) component. See (page 37).

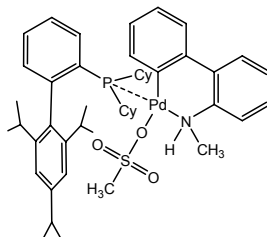


250mg
1g
5g

46-0327

NEW→

Methanesulfonato(2-dicyclohexylphosphino-2',4',6'-tri-*i*-propyl-1,1'-biphenyl)(2'-methylamino-1,1'-biphenyl-2-yl)palladium(II), min. 98% [XPhos Palladacycle Gen. 4]
 [1599466-81-5]
 $C_{47}H_{64}NO_5PPdS$; FW: 860.48; white powd.
 Note: Patents: PCT/US2013/030779, US Serial No. 13/799620. Buchwald Palladacycle Precatalyst Kit 4 (Methanesulfonato-2'-methylamino-1,1'-biphenyl-2-yl- Palladacycles Gen. 4) component. See (page 37).



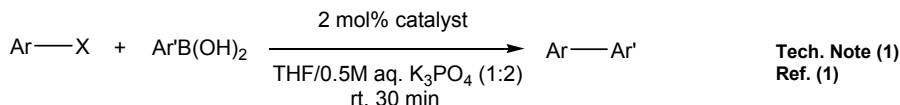
250mg
1g
5g

PALLADIUM (Compounds)

46-0327 **Methanesulfonato(2-dicyclohexylphosphino-2',4',6'-tri-*i*-propyl-1,1'-biphenyl)**
(2'-methylamino-1,1'-biphenyl-2-yl)palladium(II), min. 98% [XPhos Palladacycle Gen. 4]
 (cont.) [1599466-81-5]

Technical Note:

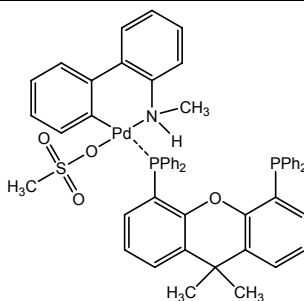
1. Palladium catalyst used in the Suzuki-Miyaura coupling of unstable boronic acids.



Reference:

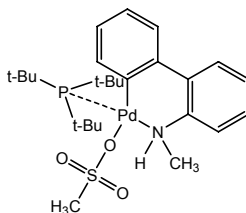
1. *J. Org. Chem.*, **2014**, 79, 4161.

46-0388 **Methanesulfonato[9,9-dimethyl-4,5-**
bis(diphenylphosphino)xanthene]
(2'-methylamino-1,1'-biphenyl-2-yl)
palladium(II), 98%
[Xantphos Palladacycle Gen. 4]
 [1621274-19-8]
 $\text{C}_{53}\text{H}_{47}\text{NO}_4\text{P}_2\text{PdS}$; FW: 950.37;
 white powdr.
 Note: Patents: PCT/US2013/030779,
 US Serial No. 13/799620. Buchwald
 Palladacycle Precatalyst Kit 4
 (Methanesulfonato-2'-methylamino-
 1,1'-biphenyl-2-yl- Palladacycles Gen. 4)
 component. See (page 37).



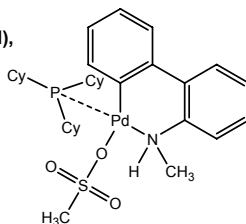
250mg
1g
5g

46-0385 **Methanesulfonato(tri-*t*-butylphosphino)**
(2'-methylamino-1,1'-biphenyl-2-yl)
palladium(II), 98%
[P(*t*-Bu)₃ Palladacycle Gen. 4]
 [1621274-11-0]
 $\text{C}_{26}\text{H}_{42}\text{NO}_3\text{PPdS}$; FW: 586.08; white powdr.
 Note: Patents: PCT/US2013/030779,
 US Serial No. 13/799620. Buchwald
 Palladacycle Precatalyst Kit 4
 (Methanesulfonato-2'-methylamino-
 1,1'-biphenyl-2-yl- Palladacycles Gen. 4)
 component. See (page 37).



250mg
1g
5g

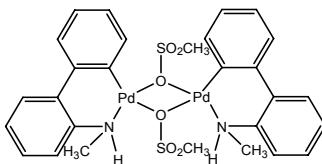
46-0379 **Methanesulfonato(tricyclohexylphosphino)**
(2'-methylamino-1,1'-biphenyl-2-yl)palladium(II),
98% [PCy₃ Palladacycle Gen. 4]
 $\text{C}_{32}\text{H}_{48}\text{NO}_3\text{PPdS}$; FW: 664.19; white powdr.
 Note: Patents: PCT/US2013/030779,
 US Serial No. 13/799620. Buchwald
 Palladacycle Precatalyst Kit 4
 (Methanesulfonato-2'-methylamino-1,1'-
 biphenyl-2-yl- Palladacycles Gen. 4)
 component. See (page 37).



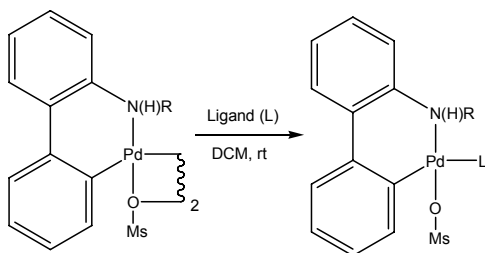
250mg
1g
5g

PALLADIUM (Compounds)**46-1553****NEW→**

(2'-Methylamino-1,1'-biphenyl-2-yl) methanesulfonatopalladium(II) dimer, min. 98% [1581285-85-9]
 $C_{28}H_{30}N_2O_6Pd_2S_2$; FW: 767.52;
 light gray powdr.

500mg
2g**Technical Note:**

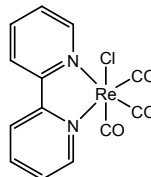
1. Dimeric palladium precursor, that when treated with phosphines at room temperature provides N-substituted precatalysts. These catalysts are useful in the aminocarbonylation of (hetero)aryl bromides, and general C-C and C-N cross-coupling reactions.

**References:**

1. *Chem. Sci.* **2013**, 4, 916.
2. *Org. Lett.*, **2013**, 15, 2876.
3. *Org. Lett.*, **2014**, 16, 4296.
4. *J. Org. Chem.*, **2014**, 79, 4161.
5. *ACS Catal.*, **2015**, 5, 1386.

RHENIUM (Compounds)**75-2360****NEW→**

Chlorotricarbonyl(2,2'-bipyridine)rhenium(I), 99% [55658-96-3]
 $C_{13}H_8ClN_2O_3Re$; yellow solid

250mg
1g**Technical Note:**

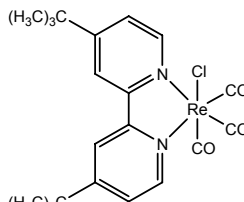
1. This catalyst is used for the reduction of carbon dioxide and carbonyls (Ref. 1-6).

References:

1. *ACS Catal.*, **2015**, 5, 900.
2. *J. Phys. Chem. Lett.*, **2014**, 5, 2033.
3. *Inorg. Chem.*, **2014**, 53, 2606.
4. *J. Am. Chem. Soc.*, **2013**, 135, 1823.
5. *Dalton Trans.*, **2013**, 42, 2062.
6. *Chem. Eur. J.*, **2012**, 18, 15722.

75-2365**NEW→**

Chlorotricarbonyl(4,4'-di-t-butyl-2,2'-bipyridine)rhenium(I), 99% [165612-19-1]
 $C_{21}H_{24}ClN_2O_3Re$; FW: 574.09; yellow solid

250mg
1g**Technical Note:**

1. This catalyst is used for the reduction of carbon dioxide.

References:

1. *J. Phys. Chem. A*, **2015**, 119, 959.
2. *Proceedings of the National Academy of Sciences of the United States of America*, **2014**, 111, 9745.
3. *Polyhedron*, **2013**, 58, 229.
4. *Inorg. Chem.*, **2010**, 49, 9283.

RHODIUM (Compounds)**45-0655** **Bromotris(triphenylphosphine)rhodium(I), 99% (99.9%-Rh)**

250mg

NEW→

[14973-89-8]

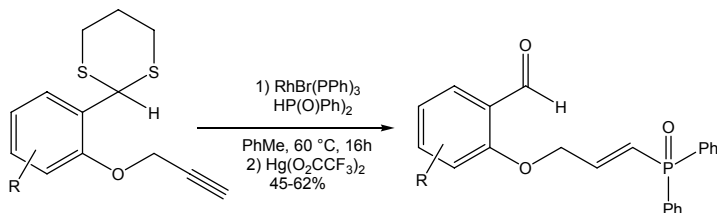
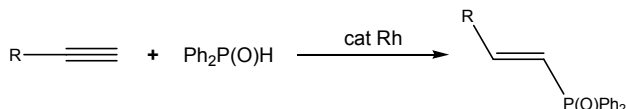
1g

C₅₄H₄₅BrP₃Rh; FW: 969.67

5g

Technical Notes:

1. Rhodium-catalyzed regio- and stereoselective addition of diphenylphosphine oxide to alkynes.
2. Rhodium-catalyzed hydrophosphinylation.

**Tech. Note (1)**
Ref. (1)**Tech. Note (2)**
Ref. (2)

References:

1. *Org. Lett.*, **2008**, *10*, 3141.
2. *J. Org. Chem.*, **2001**, *66*, 5929.

45-0355 **Carbonyl(acetylacetonato)(triphenyl-**

250mg

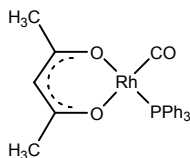
NEW→

phosphine)rhodium(I), 99% [25470-96-6]

1g

C₂₄H₂₂O₃PRh; FW: 492.31; yellow solid

5g

**RUTHENIUM (Compounds)****96-0400** **Apeiron Ruthenium Metathesis Catalyst Kit****NEW→**

See (page 11)

44-0750 **[1,3-Bis(2,6-di-*i*-propylphenyl)imidazolidin-2-ylidene][2-[[1-(methoxy(methyl)amino)-1-oxopropan-2-yl]oxy]benzylidene]ruthenium(VI) dichloride GreenCat [1448663-06-6]**

100mg

C₃₉H₅₃Cl₂N₃O₃Ru; FW: 783.33; green powdr.

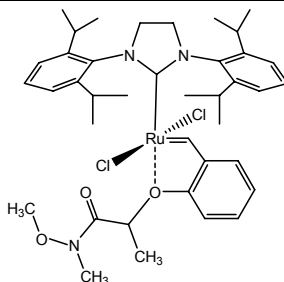
500mg

Note: Sold in collaboration with

Apeiron Synthesis, Inc.

Apeiron Ruthenium Metathesis Kit

Component. See (page 11).



Technical Note:

1. See (page 15).

RUTHENIUM (Compounds)**44-0768****NEW→**

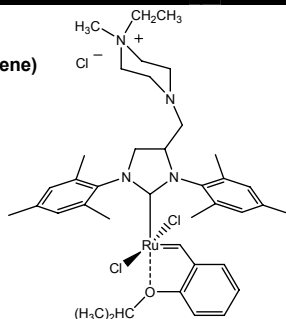
[1,3-Bis(2,4,6-trimethylphenyl)-4-[(4-ethyl-4-methylpiperazin-1-ium-1-yl)methyl]imidazolidin-2-ylidene]-(2-i-propoxybenzylidene) dichlororuthenium(VI) chloride AquaMet
[1414707-08-6]

$C_{39}H_{55}Cl_3N_4ORu$; FW: 803.31; green powdr.

Note: Sold in collaboration with

Apeiron Synthesis, Inc.

Aperion Ruthenium Metathesis Kit Component. See (page 11).



100mg

500mg

Technical Note:

1. See (page 17).

44-0758**NEW→**

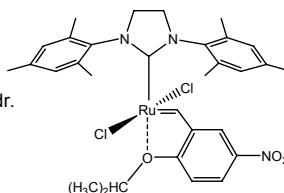
[1,3-Bis(2,4,6-trimethylphenyl-imidazolidin-2-ylidene)]-(2-i-propoxy-5-nitrobenzylidene) ruthenium(VI) dichloride nitro-Grela [502964-52-5]

$C_{31}H_{37}Cl_2N_3O_3Ru$; FW: 671.62; green powdr.

Note: Sold in collaboration with

Apeiron Synthesis, Inc.

Aperion Ruthenium Metathesis Kit Component. See (page 11).



100mg

500mg

Technical Notes:

1. See (page 19).

44-0753**NEW→**

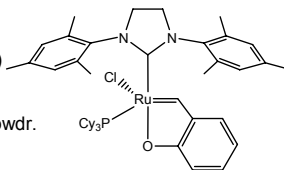
[1,3-Bis(2,4,6-trimethylphenyl-imidazolidin-2-ylidene)](tricyclohexylphosphine)-(2-oxobenzylidene) ruthenium(VI) chloride LatMet
[1407229-58-6]

$C_{46}H_{65}ClN_2OPRu$; FW: 829.52; green powdr.

Note: Sold in collaboration with

Apeiron Synthesis, Inc.

Aperion Ruthenium Metathesis Kit Component. See (page 11).



100mg

500mg

Technical Note:

1. See (page 20).

44-0765**NEW→**

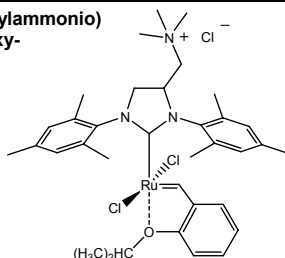
[1,3-Bis(2,4,6-trimethylphenyl)-4-[(trimethylammonio)methyl]imidazolidin-2-ylidene]-(2-i-propoxybenzylidene)dichlororuthenium(VI) chloride StickyCat Cl [1452227-72-3]

$C_{35}H_{48}Cl_3N_3ORu$; FW: 734.20; green powdr.

Note: Sold in collaboration with

Apeiron Synthesis, Inc.

Aperion Ruthenium Metathesis Kit Component. See (page 11).



100mg

500mg

Technical Note:

1. See (page 20).

44-5885**NEW→**

HAZ

Ruthenium(III) chloride hydrate (40-43% Ru) (99.99+%-Ru)

PURATREM [free of Ru(II) and Ru(IV) by electrochemical analysis] [14898-67-0]

$RuCl_3 \cdot xH_2O$; FW: 207.43; black powdr.

hygroscopic

1g

5g

SILVER (Compounds)**47-2012****NEW→**

Silver trifluoromethanesulfonate (99.95%-Ag) (Silver triflate)

[2923-28-6]

$AgSO_3CF_3$; FW: 256.94; off-white powdr.

light sensitive, hygroscopic

1g

5g

25g

CYLINDERS & ADAPTERS

95-4154

NEW→

Stainless steel cylinder, 200ml, single vertical stem, electropolished with fill-port, PCTFE valve stem tip, DOT 4B, UN stamped

Note: See the Technical Note tab at strem.com for drawings.



1cyl

95-0285

NEW→

Stainless steel cylinder, 150ml, horizontal in line, electropolished, with 1/4" VCR ball valve, gasket unplated, female nut (SC-11), DOT 4B, UN stamped



1cyl

ELECTROPOLISHED STAINLESS STEEL BUBBLERS

98-0275

NEW→

Stainless steel bubbler, 150ml, horizontal in line, electropolished with fill port, rotated valve handles

Note: See the Technical Note tab at strem.com for drawings.



1cyl

95-4155

NEW→

Stainless steel bubbler, 150ml, vertical, forward-facing high temperature valve with a metal seat (315C or 600F) electropolished with fill-port, DOT 4B, UN stamped

1cyl

95-4157

NEW→

Stainless steel bubbler, 200ml, vertical, electropolished with fill-port, high temp valves (315°C), DOT 4B, UN stamped

Note: See the Technical Note tab at strem.com for drawings.

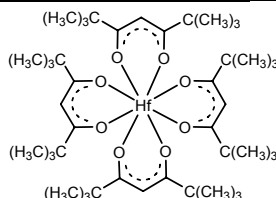


1cyl

BORON (Compounds)**05-1320****NEW→**
HAZ**Trimethylborate, 99.95+% [121-43-7]**B(OCH₃)₃; FW: 103.92; colorless liq.; m.p. -29°; b.p. 68.7°; f.p. 30°F;
d. 0.915
moisture sensitive

25g

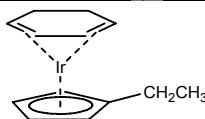
100g

HAFNIUM (Compounds)**72-7580****NEW→****Tetrakis(2,2,6,6-tetramethyl-3,5-heptanedionato)hafnium(IV), 99%**
[63370-90-1]C₄₄H₇₆HfO₈; FW: 911.56; white xtl.;

1g

5g

25g

IRIDIUM (Compounds)**77-1105****NEW→****1-Ethylcyclopentadienyl-1,3-cyclohexadieneiridium(I), 99% (99.9%-Ir) [721427-58-3]**C₁₃H₁₇Ir; FW: 365.49; pale yellow liq.

250mg

1g

IRON (Compounds)**98-4038****NEW→****Bis(N,N'-di-t-butylacetamidinato)iron(II), min. 98%, 26-0145, contained in 50 ml Swagelok® (96-1070) cylinder for CVD/ALD**
[635680-56-7]C₂₀H₄₂N₄Fe; FW: 394.42; off-white to gray xtl.; m.p. 107°C*air sensitive, moisture sensitive*

Note: Extremely air-sensitive. Contact Strem to discuss.

Product sold under, use subject to, terms and conditions of label license at www.strem.com/harvard2

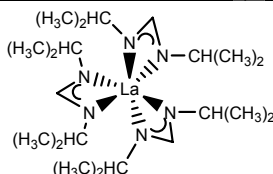
5g

LANTHANUM (Compounds)**57-1200****NEW→**
amp**Tris(N,N'-di-i-propylformamidinato)lanthanum(III), (99.999+%-La)****PURATREM**

[1034537-36-4]

C₂₁H₄₅LaN₆; FW: 520.53;

white to off-white powd.

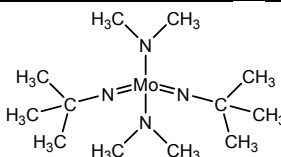
*moisture sensitive*Note: Product sold under, use subject to, terms and conditions of label license at www.strem.com/harvard2.

250mg

1g

5g

25g

MOLYBDENUM (Compounds)**42-0215****NEW→****Bis(t-butylimido)bis(dimethylamino)molybdenum(VI), 98% [923956-62-1]**C₁₂H₃₀MoN₄; FW: 326.33; orange liq.*air sensitive, moisture sensitive,**(store cold)*

500mg

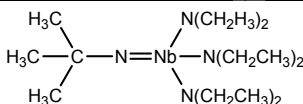
2g

NIOBIUM (Compounds)**41-0450****NEW→**

HAZ

(t-Butylimido)tris(diethylamino)niobium(V), min. 98% [210363-27-2]C₁₆H₃₉N₄Nb; FW: 380.41;

yellow to brown orange, low melting solid

air sensitive, moisture sensitive

1g

5g

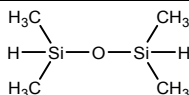
SCANDIUM (Compounds)

21-0900	Tris(cyclopentadienyl)scandium, min. 98% (99.9%-Sc) (REO)	250mg
NEW→	<i>[1298-54-0]</i>	1g
amp	(C ₅ H ₅) ₃ Sc; FW: 240.25; p.wdr.; m.p. 240°; b.p. subl. 200°/0.05mm	5g
HAZ	<i>air sensitive, moisture sensitive</i>	

SILICON (Compounds)

14-1955	Hexakis(ethylamino)disilane (99.995%-Si) PURATREM	1g
NEW→	<i>[532980-53-3]</i>	5g
HAZ	C ₆ H ₁₄ NH) ₆ Si ₂ ; FW: 320.63; colorless liq.; m.p. -7°; b.p. 257°; d. 1.0	
	<i>moisture sensitive</i>	

14-7025	1,1,3,3-Tetramethyldisiloxane, 99+%	25g
NEW→	TMDSO (99.9999%-Si) PURATREM	100g
HAZ	<i>[3277-26-7]</i>	
	C ₄ H ₁₄ OSi ₂ ; FW: 134.32; colorless liq.; b.p. 70-71°; f.p. -26°C; d. 0.76	
	<i>moisture sensitive</i>	



14-7028	Tri-<i>t</i>-butoxysilanol (99.9+%-Si) [18166-43-3]	5g
NEW→	[(CH ₃) ₃ CO] ₃ SiOH; FW: 264.43; colorless liq.; m.p. 63-65°	25g
	<i>moisture sensitive</i>	
	Note: Product sold under, use subject to, terms and conditions of label license at www.strem.com/harvard1 .	

Technical Note:

1. Silicon oxide source for rapid atomic layer deposition to prepare various nanolaminates [1] [2]

References:

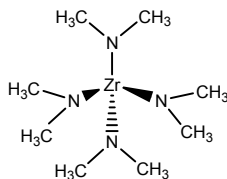
1. *Nanoscale*, **2013**, 5, 11856.
2. *Mater. Research Bulletin*, **2012**, 47, 3004.

VANADIUM (Compounds)

23-0515	Tetrakis(diethylamino)vanadium(IV), min. 95% TDEAV	250mg
NEW→	<i>[219852-96-7]</i>	1g
HAZ	V[N(CH ₂ CH ₃) ₂] ₄ ; FW: 339.46; green liq.; P.Vol. min. 95%	5g
	<i>air sensitive, moisture sensitive, (store cold)</i>	

ZIRCONIUM (Compounds)

40-4115	Tetrakis(dimethylamino)zirconium, 99% (99.99%-Zr) TDMAZ [19756-04-8]	1g
NEW→	Zr[N(CH ₃) ₂] ₄ ; FW: 267.53; light-yellow xtl.;	5g
amp	m.p. 57-60°; b.p. 80° (0.1mm)	25g
HAZ	<i>moisture sensitive, (store cold)</i>	

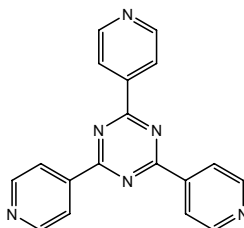


IRON (Compounds)**26-2340****NEW→**

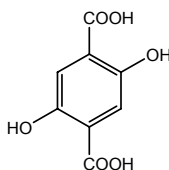
Iron(III) 1,3,5-benzenetricarboxylate hydrate, porous (F-free MIL-100(Fe), KRICT F100) [Iron trimesate] [1257379-83-1]
 $[\text{Fe}_3\text{O}(\text{H}_2\text{O})_2(\text{OH})(\text{C}_6\text{H}_3(\text{COO})_3)_2] \cdot \text{XH}_2\text{O}$;
 red solid
 Note: Sold under agreement with KRICT for research and development purposes only.
 Patents US 8507399 B2,
 US 8252950 B2.

500mg
2g**NITROGEN (Compounds)****07-3235****NEW→**

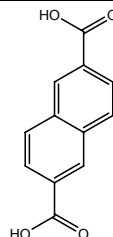
2,4,6-(Tri-4-pyridinyl)-1,3,5-triazine, min. 97% TPT [42333-78-8]
 $\text{C}_{18}\text{H}_{12}\text{N}_6$; FW: 312.33;
 off-white powdr.
 Note: Ligand for MOF synthesis.

250mg
1g
5g**OXYGEN (Compounds)****08-1220****NEW→**

2,5-Dihydroxyterephthalic acid, 98% H4DOBDC [610-92-4]
 $\text{C}_6\text{H}_2(\text{OH})_2(\text{COOH})_2$; FW: 198.13; white powdr.

1g
5g
25g**08-1235****NEW→**

2,6-Naphthalenedicarboxylic acid, min. 98% [1141-38-4]
 $\text{C}_{10}\text{H}_6(\text{COOH})_2$; FW: 216.19; white powdr.; m.p. >300°
 Note: Ligand for MOF synthesis.

5g
25g

NANOMATERIALS (Elemental forms)

47-0645

NEW→
HAZ

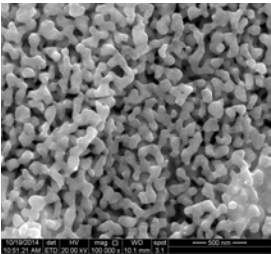
Silver Nano-Porous Catalyst
(promoted with zirconium oxide)

grey powdr.
Note: Sold under license from
OXENERGY for research purposes only.
US Patent No 8,142,938.

Strem Chemicals is pleased to offer a silver nano-porous catalyst with remarkable thermal stability up to 600 °C. The catalyst is also stable in concentrated NaOH or KOH solutions. Due to this stability, the catalyst performs well in air electrodes used in chlorinators which operate at high pH and 90°C. The catalyst also performs well in catalytic processes for ethylene oxidation and formaldehyde manufacturing, and other types of air electrodes or air fuel cells. The catalyst maintains its porous structure, and high efficiency, during continuous operations.

Specifications:

Color and form:	Grey powder
Average cluster (particle) size, micron	12-17
Average cluster porosity, %	38-42
Average pore size, nm	30-50
Specific surface area, m ² /g	6.0-7.0
Apparent density, g/ml	0.9-1.1

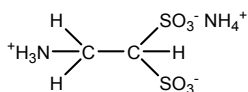


1g
5g
25g

Catalyst Analysis	Concentration
Ag	>99%
Zr	0.28-0.32%
Na	< 35 ppm
Fe	< 50 ppm
Cu	< 50 ppm

AMMONIUM (Compounds)

02-0570 **Ammonium 2-aminoethane-1,1-disulfonic acid hydrate, min. 95% [1235825-84-9]**
NEW→ $C_2H_{10}N_2O_6S_2$; FW: 222.24; white powdr.;
 m.p. 57-60°



1g
5g

Technical Note:

- This di-sulfonated building block is recommended for post-synthetic water-solubilization of hydrophobic, molecules for applications in biological media, especially organic dyes, fluorophores, azo dyes^[1], bodipy^[2], coumarin^[3] and xanthene dyes^[4]. This includes organic supramolecular compounds such as cryptophanes^[5], through aminolysis reactions of activated esters, activated carbamates (or carbonates) and isothiocyanates. Such reactions can be performed either in aqueous media (Schotten-Baumann conditions), or in anhydrous organic media (by converting this di-sulfonated taurine analog into the corresponding tributylammonium or tetrabutylammonium salt^[2,4]). Such methodology is also applicable for sulfonation of biomolecules such as peptides and nucleic acids, for fine-tuning their net electric charge^[6]. A further derivatization of this unusual amine with 3-azidopropanoic acid, 3-mercaptopropanoic acid, or 4-pentynoic acid, provides a di-sulfonated linker that is reactive in either "click" reactions (1,3-dipolar cycloadditions), S_NAr or Sonogashira

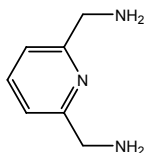
References:

- Chem.-Eur., J.*, **2013**, *19*, 1686.
- New J. Chem.*, **2013**, *37*, 1016.
- Dyes Pigm.*, **2014**, *110*, 270.
- Tetrahedron Lett.*, **2010**, *51*, 3304.
- Chem. Commun.*, **2011**, *47*, 9702.
- Bioconjugate Chem.*, **2014**, *25*, 1000.

New Products - Other Ligands

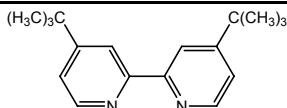
NITROGEN (Compounds)

07-0650 **2,6-Bis(aminomethyl)pyridine, min. 85%**
NEW→ [34984-16-2]
 $C_7H_{11}N_3$; FW: 137.18; low melting yellow solid
air sensitive



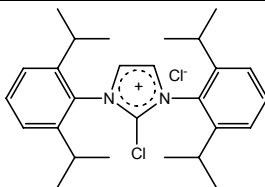
1g
5g

07-0273 **4,4'-Bis(di-t-butyl)-2,2'-bipyridine, 98% [72914-19-3]**
NEW→ $C_{18}H_{24}N_2$; FW: 268.40; white xtl.



1g
5g

07-0620 **1,3-Bis(2,6-di-i-propylphenyl)-2-chloroimidazolium chloride, 98+% [1228185-09-8]**
NEW→ $C_{27}H_{36}Cl_2N_2$; FW: 459.49;
 colorless solid
hygroscopic



250mg
1g

NITROGEN (Compounds)

07-4055

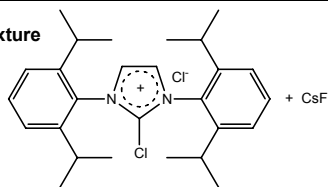
NEW→

1,3-Bis(2,6-di-*i*-propylphenyl)-2-chloroimidazolium chloride/cesium fluoride admixture (1.0/6.7 molar ratio or 1/2.2 weight ratio)

PhenoFluor®Mix [1228185-09-8]

[C₂₇H₃₆Cl₂N₂][CsF]_{6.7}; off-white solid
hygroscopic

Note: Product sold under, use subject to, terms and conditions of label license at www.strem.com/harvard4



250mg

1g

Note:

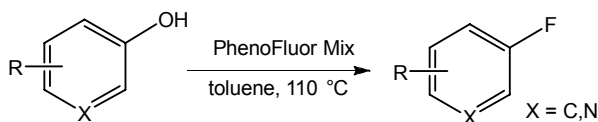
Weight-percent of components:

31.2 wt% chloroimidazolium chloride

68.8 wt% cesium fluoride

Technical Notes:

1. PhenoFluor®Mix is a bench-stable mixture used for the deoxyfluorination of phenols, including electron-deficient and rich phenols, as well as heterocycles. The reaction is operationally simple and scalable.
2. See references 2 to 4 for additional uses of PhenoFluor®.



References:

1. *Org. Process Res. Dev.*, **2014**, *18*, 1041.
2. *J. Am. Chem. Soc.*, **2013**, *135*, 2470.
3. *J. Am. Chem. Soc.*, **2011**, *133*, 11482.
4. *Org. Lett.*, **2015**, *17*, 544.

07-0287

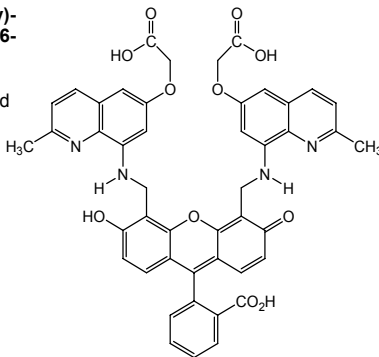
NEW→

2-[4,5-Bis{[6-(2-ethoxy-2-oxohydroxy)-2-methylquinolin-8-ylamino)methyl]-6-hydroxy-3-oxo-3H-xanthen-9-yl}benzoic acid FL2A [1239877-07-6]

C₄₆H₃₆N₄O₁₁; FW: 848.85; dark-red solid

Note: Nitric Oxide Sensor

(Intracellular) Kit ("NO-ON") (FL2) component. See (page 36).



0.5mg

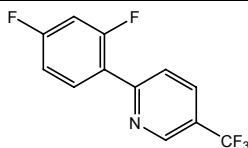
07-4040

NEW→

2-(2,4-Difluorophenyl)-5-(trifluoromethyl)pyridine, 98% dF(CF₃)ppy [387827-64-7]

C₁₂H₆F₅N; FW: 259.18;

off-white microxtl.; m.p. 59.0-62.1°



250mg

1g

07-0458

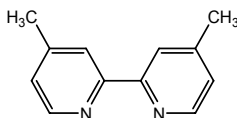
NEW→

4,4'-Dimethyl-2,2'-bipyridine, 99%

[1134-35-6]

C₁₂H₁₂N₂; FW: 184.24;

white to off-white powd.



1g

5g

25g

07-0510

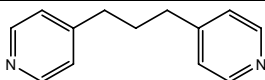
NEW→

1,3-Di-(4-pyridyl)propane, 98%

[17252-51-6]

C₁₃H₁₄N₂; FW: 198.26;

light yellow xtl.



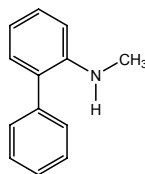
5g

25g

NITROGEN (Compounds)

07-1158 2-(N-Methylamino)-1,1'-biphenyl, min. 95%

[14925-09-8]

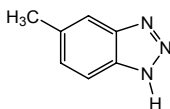
 $C_{13}H_{13}N$; FW: 183.25; pale-yellow liq.*air sensitive*

250mg

1g

5g

07-1215 5-Methyl-1H-benzotriazole, 99% [136-85-6]

 $C_7H_7N_3$; FW: 133.15; white to off-white solid

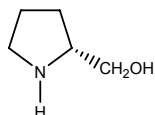
25g

100g

500g

07-1895 (R)-(-)-2-Pyrrolidinemethanol, 99%

(D-Prolinol) [68832-13-3]

 $C_5H_{11}NO$; FW: 101.15; light-yellow, viscous liq.; $[\alpha]_D^{20}$ -31° (c 1.0, toluene); b.p. 74-76° (2mm); d. 1.025*air sensitive*

1g

5g

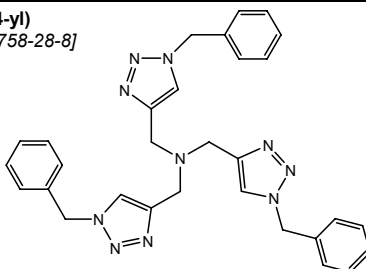
25g

07-3215 Tris[(1-benzyl-1H-1,2,3-triazol-4-yl)methyl]amine, 97% TBTA [510758-28-8]

 $C_{30}H_{30}N_{10}$; FW: 530.63;

white to off-white powdr.

(store cold)



250mg

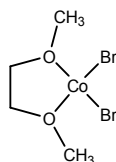
1g

CHROMIUM (Compounds)

24-0190	Chromium(III) bromide, anhydrous flakes, 99% [10031-25-1]	1g
NEW→	CrBr ₃ ; FW: 291.71; dark-green flakes	5g
HAZ	<i>hygroscopic</i>	

COBALT (Compounds)

27-0350	Cobalt(II) bromide, dimethoxyethane adduct, min. 98% [18346-57-1]	1g
NEW→	CoBr ₂ ·CH ₃ O(CH ₂) ₂ OCH ₃ ; FW: 308.86; blue powdr.	5g
	<i>moisture sensitive</i>	

**GALLIUM (Compounds)**

31-1370	Gallium (III) fluoride trihydrate (99.99%-Ga) PURATREM	1g
NEW→	[7783-51-9]	5g
	GaF ₃ ·3H ₂ O; FW: 126.72 (180.76); white xtl.	
	<i>hygroscopic</i>	

MANGANESE (Compounds)

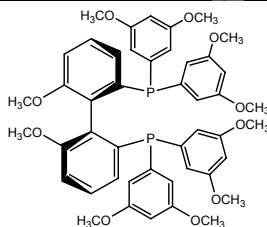
25-1250	Manganese(II) bromide, tetrahydrofuran adduct, min. 98%	1g
NEW→	[57298-42-7]	5g
	MnBr ₂ (C ₄ H ₈ O) ₂ ; FW: 358.96; light pink-orange powdr.	25g
	<i>moisture sensitive</i>	

NITROGEN (Compounds)

96-0397	Nitric Oxide Sensor (Intracellular) Kit ("NO-ON") (FL2A)	
NEW→	(Cell-trappable NO fluorescent probe)	
	<i>See (page 36)</i>	

PHOSPHORUS (Compounds)

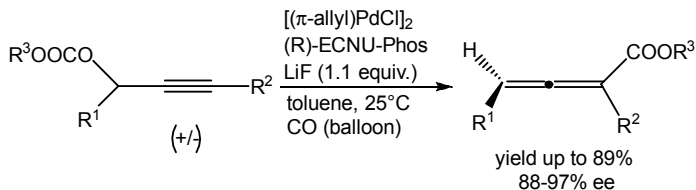
15-0185
NEW→ **(R)-(+)-2,2'-Bis[di(3,5-dimethoxyphenyl)phosphino]-6,6'-dimethoxy-1,1'-biphenyl, 98% (R)-ECNU-Phos [1448722-98-2]**
 $C_{46}H_{48}O_{10}P_2$; FW: 822.82; white solid;
 $[\alpha]_D^{25} +18.1^\circ$ (c 1.01, $CHCl_3$);
 m.p. 236-237°
air sensitive, (store cold)
 Note: Sold under license from ECNU for research purposes only.
 Patent CN201310135176.3.



25mg
 100mg

Technical Note:

1. Efficient ligand for the highly enantioselective synthesis of optically active 2,3-allenoates via carbonylation of racemic propargylic carbonates.

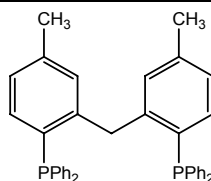


Tech. Note (1)
Ref. (1)

Reference:

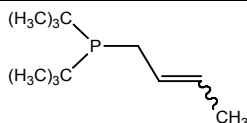
1. *J. Am. Chem. Soc.*, **2013**, 135, 11517.

15-0358
NEW→ **Bis[2-(4-methyldiphenylphosphino)phenyl]methane, 90%**
 $C_{39}H_{34}P_2$; FW: 564.64; white powdr.



100mg
 500mg
 2g

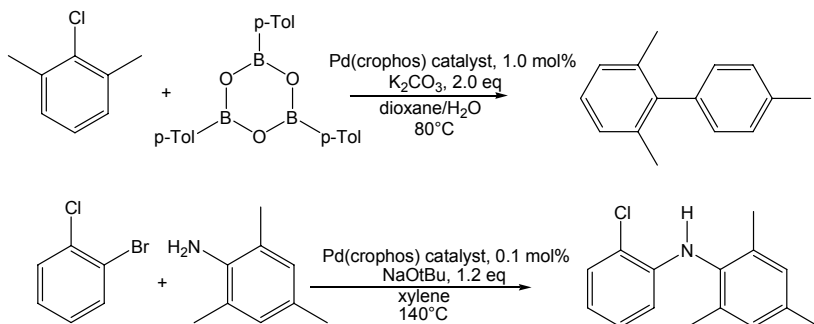
15-1725
NEW→ **Di-t-butyl(2-butenyl)phosphine (40% in xylene), 98% m-Crophos®**
 $C_{12}H_{26}P$; FW: 200.30; colorless liq.;
 b.p. 76-77° (4.0mm)
air sensitive



5g
 25g
 100g

Technical Note:

1. Crophos® is a very reactive phosphine ligand used in catalysts that are especially effective for coupling reactions involving bulky reactants.

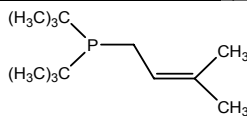


PHOSPHORUS (Compounds)

15-1729

NEW→
HAZ

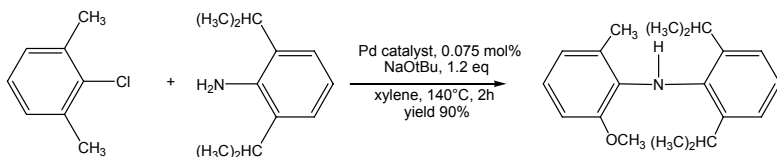
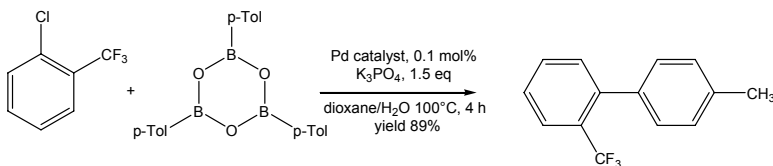
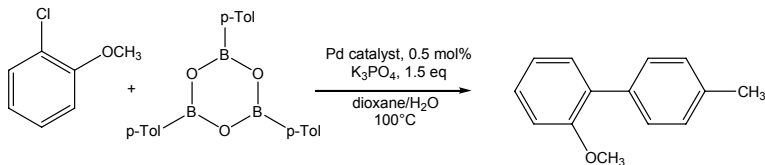
Di-t-butyl(3-methyl-2-butenyl)phosphine (H₃C)₃C-
(40% in xylene), 98% Crophos®
C₁₃H₂₇P; FW: 214.33; colorless liq.
air sensitive



5g
25g
100g

Technical Note:

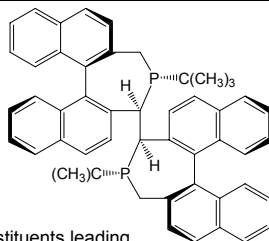
1. m-Crophos® is a very reactive phosphine ligand used in catalysts that are especially effective for coupling reactions involving bulky reactants.



15-1053

NEW→

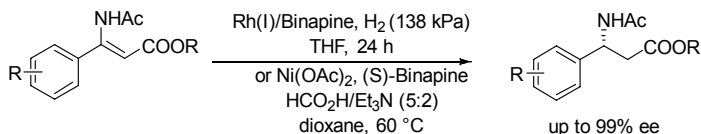
**(3S,3'S,4S,4'S,11bS,11'bS)-(+)-4,4'-
Di-t-butyl-4,4',5,5'-tetrahydro-3,3'-bi-
3H-dinaphtho[2,1-c:1',2'-e]phosphepin,
97% (S)-BINAPINE [610304-81-9]**
C₅₂H₄₈P₂; FW: 734.89; white powd.
air sensitive
Note: Sold in collaboration with Chiral
Quest for research purposes only.
US Patent No. 7105702, 7153809, 7169953.



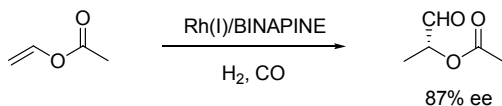
50mg
250mg

Technical Notes:

1. Phosphorus chirality restricts rotation of adjacent substituents leading to effective chiral induction, and the highly electron-donating bisphosphine leads to high activities.
2. Rh-Binapine and Ni-Binapine complexes form excellent catalysts for asymmetric (transfer) hydrogenation of aryl substituted olefins to form β -amino acids.
3. Rh-Binapine complexes give high enantioselectivities in asymmetric hydroformylations of styrene, allyl cyanides, and vinyl acetates.



**Tech. Note (2)
Ref. (1,2)**



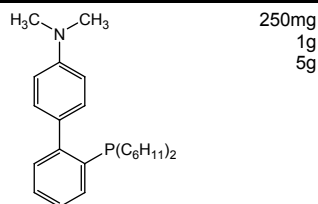
**Tech. Note (3)
Ref. (3)**

References:

1. *Angew. Chem. Int. Ed.*, **2003**, 42, 3509.
2. *Angew. Chem. Int. Ed.*, **2014**, 53, 12210.
3. *Organometallics*, **2006**, 25, 5003.

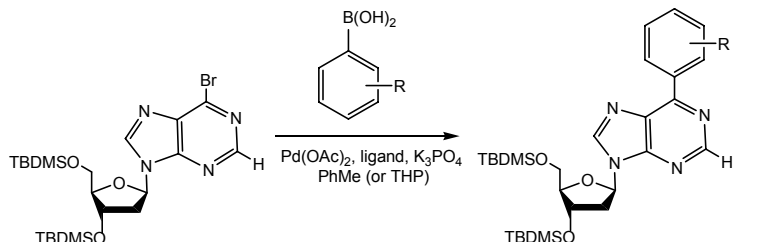
PHOSPHORUS (Compounds)

15-1154 **2-Dicyclohexylphosphino-4'-(N,N-dimethylamino)-1,1'-biphenyl, 98% [1185899-00-6]**
NEW→ $C_{26}H_{36}NP$; FW: 393.55; white xtl.
 Note: Patents: US 6,395,916, US 6,307,087.



Technical Note:

- Ligand used in the palladium-catalyzed C-C bond formation in a substituted deoxyguanosine.

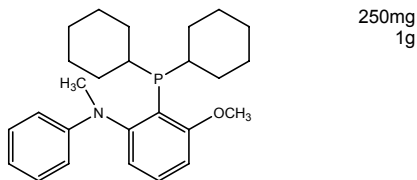


Tech. Note (1)
Ref. (1)

Reference:

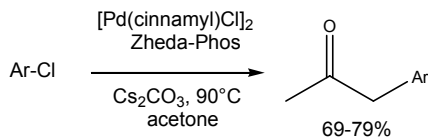
- J. Am. Chem. Soc.*, **2009**, 131, 12.

15-6528 **[2-Dicyclohexylphosphino-3-methoxy-N-methyl-N-phenylbenzenamine, 98% Zheda-Phos [1398565-95-1]**
NEW→ $C_{26}H_{36}NOP$; FW: 409.54; white powdr.; m.p. 169-170°
 Note: Sold under license from ZJU for research purposes only.
 Patent CN201210146220.6, PCT/CN2012/078129.



Technical Note:

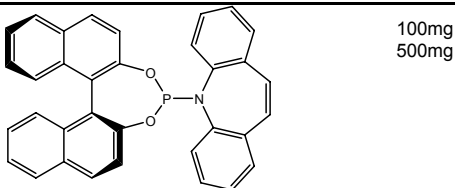
- Ligand/Pd catalyst used in the general α -monoarylation of acetone with aryl chlorides.



Reference:

- Adv. Synth. Catal.*, **2013**, 355, 1255.

15-1227 **(S)-(+)-(3,5-Dioxa-4-phosphacyclohepta[2,1-a;3,4-a']dinaphthalen-4-yl)-5H-dibenz[b,f]azepine, min. 97% [942939-38-0]**
NEW→ $C_{34}H_{22}NO_2P$; FW: 507.52; yellow solid
air sensitive, moisture sensitive



Technical Notes:

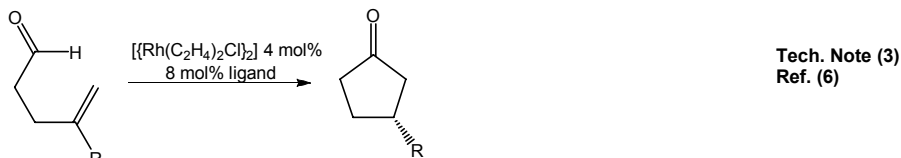
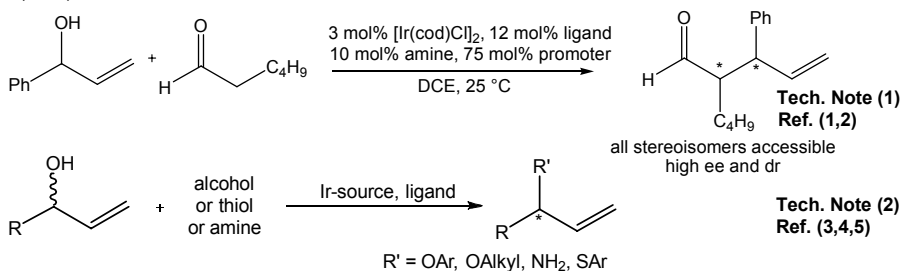
- The ligand is used in the stereodivergent α -allylation of linear aldehydes with dual iridium and amine catalysis.
- The ligand used in the direct, enantioselective iridium-catalyzed amination and (thio-) etherification of racemic allylic alcohols.
- The ligand used in an asymmetric, rhodium-catalyzed, intramolecular hydroacylation reaction.

PHOSPHORUS (Compounds)

15-1227

NEW→

(cont.)

(S)-(+)-(3,5-Dioxa-4-phosphacyclohepta[2,1-a;3,4-a']dinaphthalen-4-yl)-5H-dibenz[b,f]azepine, min. 97% [942939-38-0]

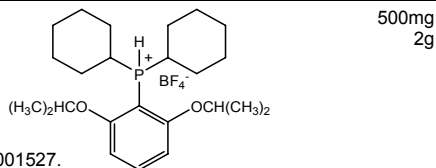
References:

1. *J. Am. Chem. Soc.*, **2014**, 136, 3020.
2. *Science*, **2013**, 340, 1065.
3. *Angew. Chem. Int. Ed.*, **2012**, 51, 3470.
4. *Angew. Chem. Int. Ed.*, **2012**, 51, 8652.
5. *Angew. Chem. Int. Ed.*, **2011**, 50, 5568.
6. *Angew. Chem. Int. Ed.*, **2011**, 50, 10670.

15-6525

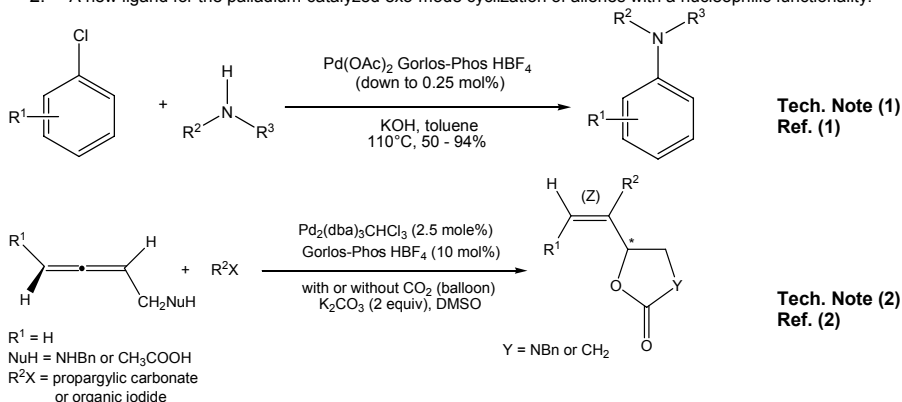
NEW→

[2,6-Di-*i*-propoxyphenyl]dicyclohexylphosphonium tetrafluoroborate, 98% GorlosPhosHBF₄ [1268824-69-6]
 C₂₄H₄₀BF₄O₂P; FW: 478.35; white solid;
 m.p. 221.6-223.2 °C
 Note: Sold under license from ZJU for research purposes only.
 Patents ZL200910154029.4, PCT/CN2009/001527.



Technical Notes:

1. A new ligand for the palladium-catalyzed amination reactions of aryl chlorides with potassium hydroxide as the base.
2. A new ligand for the palladium-catalyzed exo-mode cyclization of allenes with a nucleophilic functionality.



References:

1. *Adv. Synth. Catal.*, **2011**, 353, 100.
2. *Org. Biomol. Chem.*, **2013**, 11, 5370.

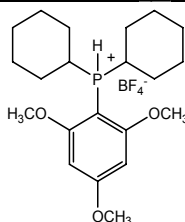
PHOSPHORUS (Compounds)

15-6520

NEW→

[2,4,6-Trimethoxyphenyl]dicyclohexylphosphonium tetrafluoroborate, 98% LB-Phos.HBF₄ [1217887-12-1]
 C₂₁H₃₄BF₄O₃P; FW: 452.27; white solid;
 m.p. 142.6-143.4°

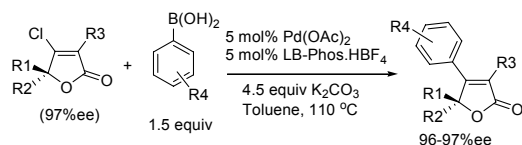
Note: Sold under license from ZJU for research purposes only. Patents ZL200910154029.4, PCT/CN2009/001527



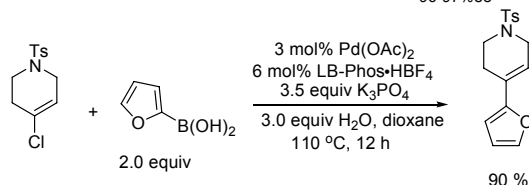
500mg
2g

Technical Notes:

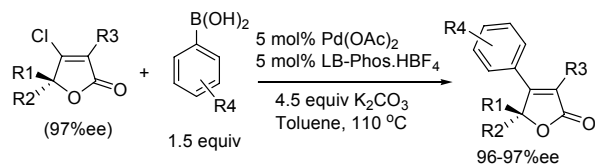
1. Suzuki-coupling reaction of aryl or 1-alkenyl chlorides.
2. Suzuki-coupling reactions of substituted furans.
3. Highly selective Suzuki-coupling of C-Cl bonds in β -chlorobutenelides.
4. Palladium-catalyzed Suzuki-coupling reactions of chloroalkylidene- β -lactones.
5. Suzuki-coupling reactions of chloro-substituted cyclopentadienylindoles.
6. Efficient synthesis of 4-halo-2,5-dihydro-1,2-oxaphosphate-2-oxides from 1,2-allenylphosphates.
7. Palladium-catalyzed reaction of 2,3-allenoates with a 1,3-diketone.
8. Suzuki-coupling of chloro-substituted benzofurans with arylboronic acids.
9. Suzuki-coupling of 2-bromoalken-3-ols with alkylboronic acids.
10. Copper-catalyzed hydroboration of alkynamides with B₂pin₂.



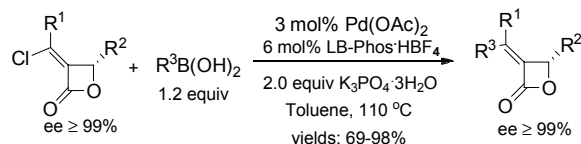
Tech. Note (1)
Ref. (1)



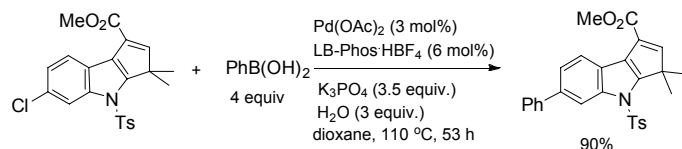
Tech. Note (2)
Ref. (2)



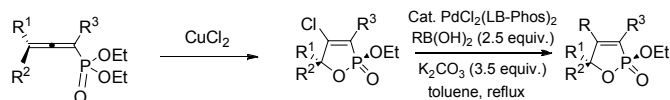
Tech. Note (3)
Ref. (3)



Tech. Note (4)
Ref. (4)



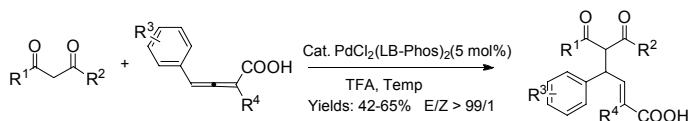
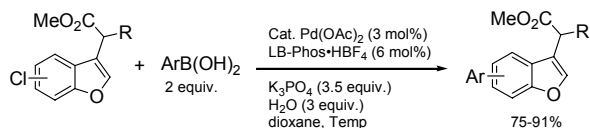
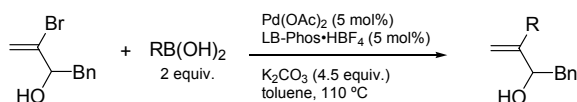
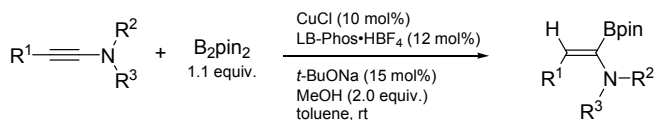
Tech. Note (5)
Ref. (5)



Tech. Note (6)
Ref. (6)

PHOSPHORUS (Compounds)

15-6520

NEW→
(cont.)**[2,4,6-Trimethoxyphenyl]dicyclohexylphosphonium tetrafluoroborate, 98%**
LB-PhosHBF₄ [1217887-12-1]**Tech. Note (7)**
Ref. (7)**Tech. Note (8)**
Ref. (8)**Tech. Note (9)**
Ref. (9)**Tech. Note (10)**
Ref. (10)

References:

1. *Tetrahedron Lett.*, **2010**, 51, 1284.
2. *Chem. Commun.*, **2012**, 48, 12074.
3. *Chem. Eur. J.*, **2010**, 16, 6434.
4. *Org. Biomol. Chem.*, **2013**, 11, 98.
5. *Org. Lett.*, **2012**, 14, 3616.
6. *Eur. J. Org. Chem.*, **2012**, 3806.
7. *Eur. J. Org. Chem.*, **2012**, 2585.
8. *Org. Lett.*, **2012**, 14, 720.
9. *Eur. J. Org. Chem.*, **2012**, 4034.
10. *Org. Biomol. Chem.*, **2014**, 12, 5945.

15-6558

NEW→
HAZ**Trimethylphosphite, 99% [121-45-9]**(CH₃O)₃P; FW: 124.08; colorless liq.; b.p. 110-112°; f.p. 82°F;
d. 1.052
air sensitive

50g

250g

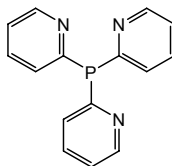
15-7945

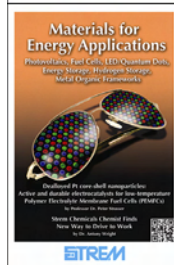
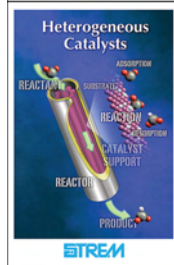
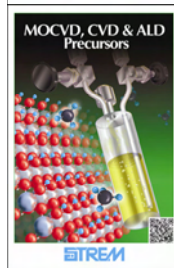
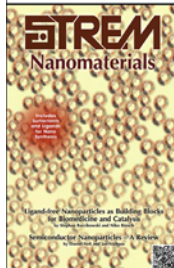
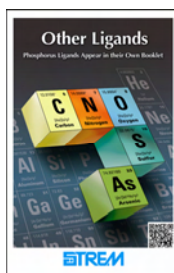
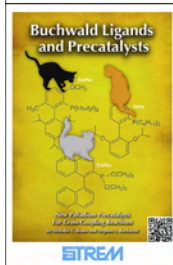
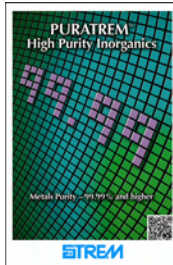
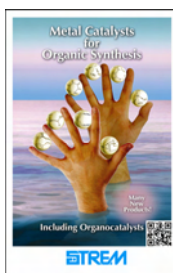
NEW→

Tris(2-pyridyl)phosphine, min. 97%
[26437-48-9](C₅H₄N)₃P; FW: 265.25;
white to off-white powdr.; m.p. 112-114°
air sensitive

250mg

1g





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