

THE STREM CHEMIKER

VOL. XXIV No.1

May, 2009

Gold Catalysts and Nanoparticles

New Trends in Research

The Relevance of Shape and Size of Gold Nanoparticles

Günter Schmid

Recent Developments in Gold Catalysis

Rubén S. Ramón, Sylvain Gaillard and Steven P. Nolan

Capabilities of AUROlite™ Catalysts

Jason S. McPherson and David T. Thompson



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The Strem Chemiker

Vol. XXIV, No. 1

May, 2009

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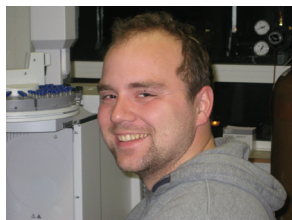
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Biographical Sketches

Prof. Dr. Günter Schmid studied chemistry at the University of Munich and finished his Ph.D. in Inorganic Chemistry in 1965. In 1966 he moved to the University of Marburg, Germany, where he performed his Habilitation that was completed in 1969. Two years later he got a professorship at the same university. From 1975 – 1976 he was the dean of the chemical faculty in Marburg. In 1977 he followed a call to the chair for Inorganic Chemistry at the University of Essen, where he acted as the director of the Institute for Inorganic Chemistry until 2002, when he retired. Since then he is working as an emeritus. In 1982 he was a visiting professor at University of California, Los Angeles. From 1977 until 2002 Prof. Schmid occupied several academic positions. From 1987 – 1988 he was the dean of the chemical faculty and from 1988 – 1992 he was a member of the rectorate of the university, responsible for research. Prof. Schmid's scientific interests were and still are focused on the synthesis, investigation and application of transition metal nanoparticles, mainly on the fields of catalysis, medicine and future storage devices. He published about 350 original scientific papers and edited four books on nanoparticles and nanotechnology. He is a member of several editorial boards of international journals. In 2003, Prof. Schmid received the Wilhelm-Klemm-Award from the German Chemical Society for his work in nanoscience and nanotechnology.



Steven P. Nolan received his B.Sc. in Chemistry from the University of West Florida and his Ph.D. from the University of Miami where he worked under the supervision of Professor Carl D. Hoff. After a postdoctoral stay with Professor Tobin J. Marks at Northwestern University, he joined the Department of Chemistry of the University of New Orleans in 1990. In 2006, he joined the Institute of Chemical Research of Catalonia (ICIQ) as Group leader and ICREA Research Professor. In early 2009, he joined the School of Chemistry at the University of St Andrews where he holds a Chair in Chemistry.



Rubén S. Ramón received his Diploma in Chemistry at the Julius-Maximilians-Universität Würzburg. In 2007, he obtained a pre-doctoral position in the research group of Professor Steven P. Nolan at the Institute of Chemical Research of Catalonia (ICIQ) in Tarragona. In 2009, he followed him to the University of St Andrews. His research is focused on the development of gold complexes and their application in catalysis.

Biographical Sketches (cont.)



Dr. Sylvain Gaillard received his M.Sc. and Ph.D. from the Université Paul Cézanne/Aix-Marseille III where he worked under the supervision of Dr. Alphonse Tenaglia, on platinum and ruthenium catalysis. He obtained a postdoctoral position with Professors Renaud and Thomas and Dr. Fischmeister at the ENSCR in Rennes where he studied new nitrogen ligands in organometallic catalysis. He is currently pursuing post-doctoral studies in St Andrews with Professor Steven P. Nolan.

David Thompson has more than 45 years experience in precious metal catalysis, including almost 30 in ICI and Johnson Matthey, and for the last 14 he has been monitoring and encouraging participation in the exciting new developments in the catalysis of gold, especially its applications in environmental control, chemical synthesis, the hydrogen economy and sensors. He is co-author of 'Catalysis by Gold', the first book on gold catalysis, and a consultant to Project AuTEK (Mintek, South Africa) and the World Gold Council (London, UK). He obtained his PhD in organic chemistry in 1958 from Imperial College, London, and was then a Research Fellow at the University of California, Los Angeles and Imperial College before joining ICI in 1962.



Jason McPherson completed his postgraduate studies in precious metal catalysis at the University of Cape Town (South Africa) in 2003. Currently Jason heads up the Scale-up and Commercialisation Unit of Project AuTEK's Catalysis Programme (Mintek, South Africa) and as such is actively involved in the production, marketing and application of AuTEK's AUROLiteTM range of gold catalysts. He is highly active in application areas such as CO oxidation, preferential oxidation, liquid phase oxidations (e.g. glucose, glycerol), and selective hydrogenation. As such he is also a technology advisor to the World Gold Council (London, UK).



The Relevance of Shape and Size of Gold Nanoparticles

By Günter Schmid

Gold, the most noble metal, fascinated mankind since its discovery. The reasons are manifold: The unique colour and lustre made gold a desirable material in art from ancient years up to date, not only for its beautiful appearance, but also for its chemical inertness making objects optically unchanged for millennia. Due to its monetary value this metal occasioned murders and wars. It still is more stable in value than paper money and therefore many nations hold gold to defend their currencies. The financial status of the world economy is indicated by the price of gold. Beyond bulk gold, the element was already used in a special form in ancient India for medical reasons and in Roman times to colour glass, namely as nanoparticles. Gold nanoparticles are red, purple or bluish in colour and are therefore still used for decorative purposes. The fact was known in ancient times but, of course, nobody could understand the reason for this phenomenon. The first person who scientifically investigated the colour change of gold at reduced particle size was Michael Faraday (1857). From a physical point of view we nowadays understand the yellow colour of bulk gold as well as the colour change at the nanoscale. Einstein's theory of relativity explains the special interaction of bulk gold with visible light, the reason for the yellow colour. Mie's theory quantitatively explains the reason for the beautiful colours of gold nanoparticles. Relativistic effects are meanwhile well understood and explain special effects in gold chemistry. Figure 1 shows the two prominent colours of bulk gold and of gold nanoparticles in ruby glass.



a



b

Figure 1: The colour of bulk gold (a) and gold nanoparticles in glass (b)

The practical value of these ligand exchanges is to be seen in the change of solubility in different solvents. The PPh_3 protected compound is most soluble in dichloromethane. Water soluble derivatives result by introduction of ionic ligands like $[\text{B}_{12}\text{H}_{12}\text{SH}]^{2-}$ or $\text{Ph}_2\text{PC}_6\text{H}_4\text{SO}_3^-$. The non-polar silsequioxane makes the compound soluble even in *n*-pentane. The ligands in $\text{Au}_{55}(\text{PPh}_3)_{12}\text{Cl}_6$ can also be quantitatively removed and bare Au_{55} can be generated that organize themselves to $(\text{Au}_{55})_n$ superstructures [1].

One of the most fascinating properties of this special representative of gold nanoparticles is its electronic behaviour. Due to the ultimate size of the Au_{55} nucleus (1.4 nm), its nature is no longer metallic but follows quantum mechanical rules and behaves as a typical quantum dot (QD), even at room temperature. Only slightly larger particles like the four-shell cluster $\text{Pt}_{309}(\text{phen}^*)_{30}$ (phen^* = sulfonated phenanthroline) with 1.8 nm core size, shows its QD behaviour only at low temperatures. In Figure 3 is model of $\text{Au}_{55}(\text{PPh}_3)_{12}\text{Cl}_6$ (a) oriented to match the image obtained from a scanning tunnelling microscopic (STM) image (b) of a single cluster.

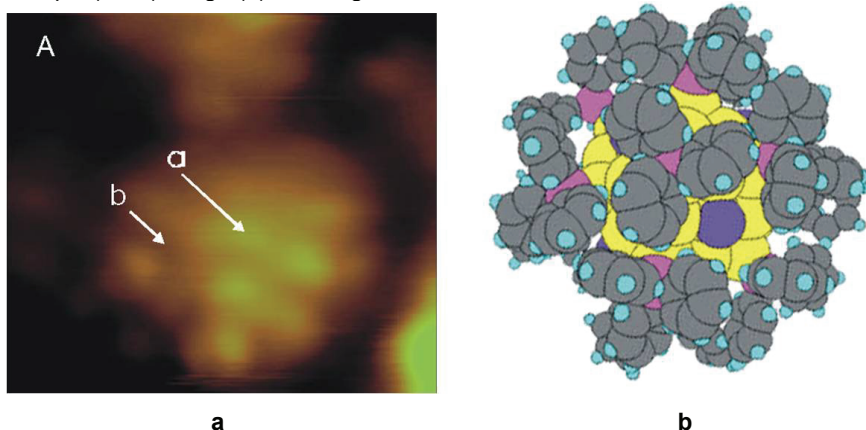


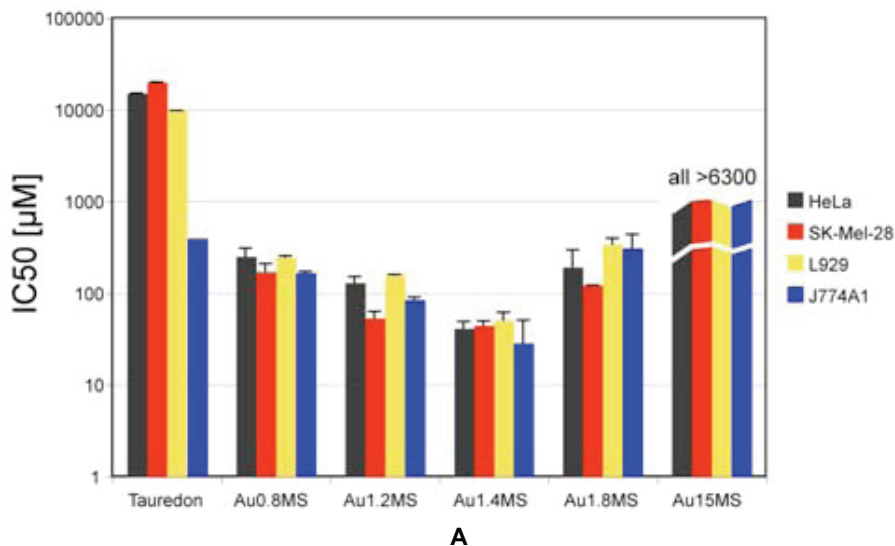
Figure 3: Scanning tunnelling microscopic image (a) and model of $\text{Au}_{55}(\text{PPh}_3)_{12}\text{Cl}_6$

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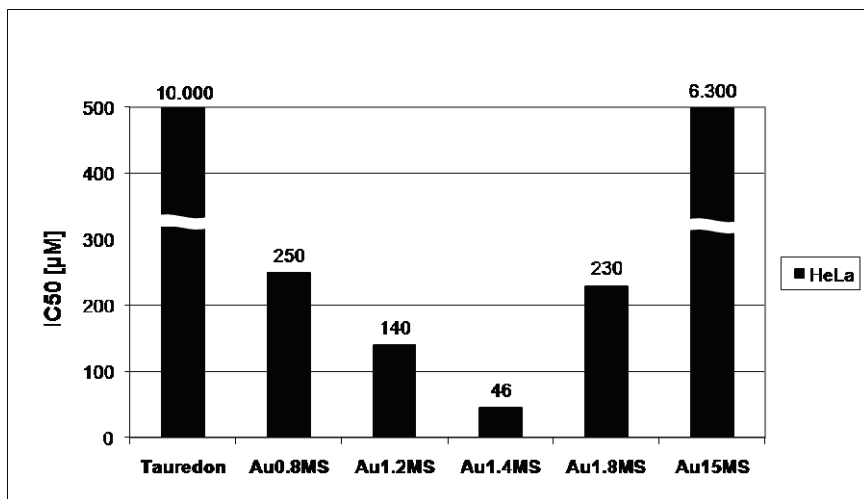
Scanning tunneling spectroscopy (STS) at the two different positions a and b show that the QD behaviour is not influenced by the ligands between tip and Au_{55} nucleus. At low temperature even details of the inner electronic structure of the nanoparticle can be observed with discrete electronic energy levels. For that reason such QDs are also called "big atoms". Besides the scientific interest in those species, there is an enormous practical interest in room temperature QDs, since they can act as single electron switches and in principle also as single electron transistors, promising tremendous importance in future nanoelectronics. Compared with today's transistors using several hundred thousands of electrons per switch, Au_{55} QDs would be able to function with one single electron! The consequences do not need to be elucidated. Of course, the development of a working device is an enormous challenge, especially due to the complication of needing to individually address the particles from the outside. First attempts to organize them in an

appropriate manner have begun and give some hope with respect to further progress in this direction.

Presently, there is a world-wide discussion on the toxicity of nanoparticles. General declarations on the toxicity or non-toxicity of nanoparticles are absolutely unusable. The biological response on nanoparticles depends on too many factors so that a general rule cannot be established. First of all it is the size of a particle that determines the manner of transport in a living system. The chemical composition is another decisive point, including the nature of the surface. The first contact between a biological system and a nanoparticle happens via its surface. All these aspects have to be considered before discussing toxicity problems. Unfortunately, there exist almost no real systematic investigations in that sense. For instance, numerous contradictory results have become known about toxicity of Au nanoparticles. However, the lack of these investigations is clear: there is almost no information on size-dependency and influence of the protecting ligand shell. The only relevant study with such conditions well defined shall be briefly discussed in the following. Gold nanoparticles of 0.8, 1.2⁺, 1.4 (Au₅₅), 1.8⁺ and 15 nm in diameter, all protected by monosulfonated triphenylphosphine (MS), were used to test cell toxicity of various human cancer cell lines. From Figure 4a it can clearly be seen that the smallest micro-molar amount to reach IC₅₀ values (the amount to kill 50% of the cells) occurred with 1.4 nm size particles (Au1.4MS), i.e. this is the most toxic compound of all gold nanoparticles. Figure 4b shows the result for HeLa cells in a linear scaling to emphasize the size-dependency of toxicity compared with the logarithmic scaling in 4a. 15 nm gold particles as well as Tauredon, a gold thiomalate complex, do not show any visible toxicity.



*) From Strem Chemicals, Inc. Newburyport, MA 01950-4098, USA



B

Figure 4: (a) Comparison of IC₅₀ values of four different cell lines with different Au nanoparticles in logarithmic scaling. (b) Linear scaling of the values with HeLa cells.

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The extreme toxicity of $\text{Au}_{55}(\text{PPh}_2\text{C}_6\text{H}_4\text{SO}_3\text{Na})_{12}\text{Cl}_6$ (1.4MS) prompted additional toxicity tests with a series of a dozen other cancer cell lines. In every case the special behaviour of these 1.4 nm Au particles became visible. The sharp maximum in toxicity at 1.4MS, even over the narrow range of 1.2MS to 1.8MS can only to be explained by a very specific behaviour of the Au_{55} clusters with cell components. An important aspect in this connection is the fact that the non-toxic phosphine ligands are easily removed from the gold cores in solution so that direct interactions between the Au cores and cell components become possible. One such specific interaction is well known: the 1.4 nm Au_{55} core fits perfectly into the major groove of DNA as can be seen from the calculated model shown in Figure 5.

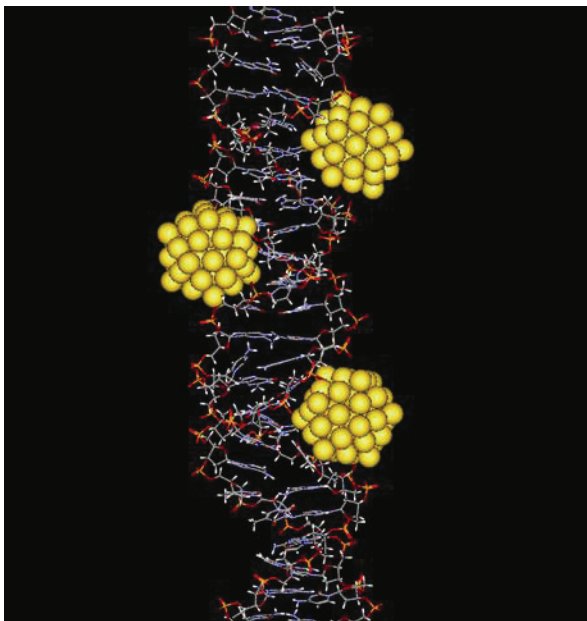


Figure 5: Result of molecular modelling calculations of the interaction of Au₅₅ particles with the major grooves of B-DNA.

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However, additional experiments showed also mitochondrial damage, combined with oxidative stress, leading to marked necrosis [2]. The special role of the non-toxic sulfonated triphenylphosphine with respect to its easy substitution is shown by the use of species with strong, non-replaceable ligands that turned out to be non-toxic. The reason is to be seen in the very strong Au-S bonds so that no bare Au₅₅ cores can be formed and the specific interactions with cell components will not happen [2].

Finally, another size-specific phenomenon of gold nanoparticles shall be mentioned: the biodistribution in living animals. A comparison of 1.4 nm and 18 nm gold particles, both protected again by Ph₂PC₆H₄SO₃Na, showed significant differences in biodistribution over all organs of rats after intratracheal instillation as well as after intravenous injection within 24 h [3]. As can be seen from Figure 6a, the 18 nm particles are almost quantitatively removed from the blood after intravenous injection and are trapped in the liver (ca. 95 %) and in the spleen (ca. 2 %), whereas the Au₅₅ particles (Figure 6b) are found in the liver with less than 50 %. The other half of the particles is distributed in lung, spleen, kidneys, heart, uterus, urine, blood and skin.

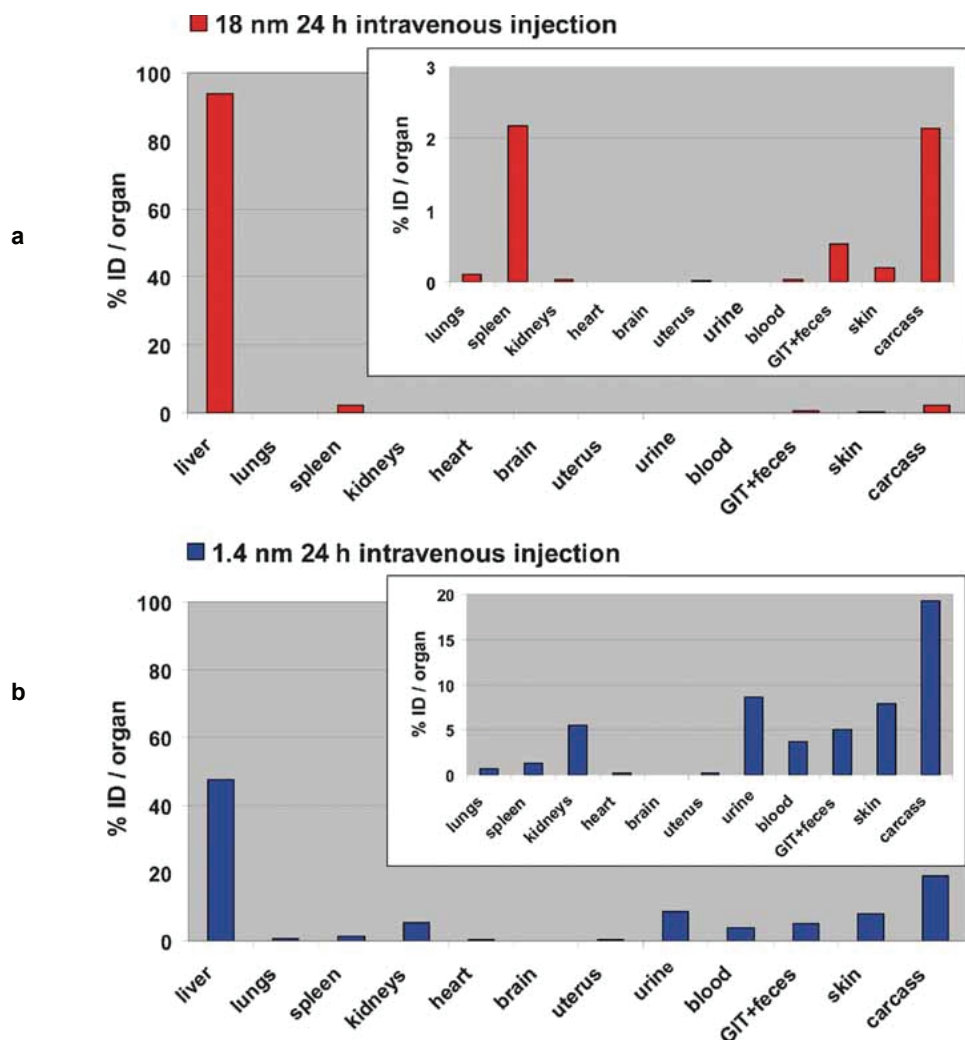


Figure 6: Biodistribution of 18 nm (a) and 1.4 nm (b) Au particles after intravenous injection

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Figure 7a and b show the distribution of the two kinds of particles after intratracheal instillation. Almost 100 % of the 18 nm species are found in the lung after 24 h. About 90% of the 1.4 nm particles are also found in the lung, however, the other 10 % are trapped in liver, spleen, kidneys, uterus, urine, blood and skin.

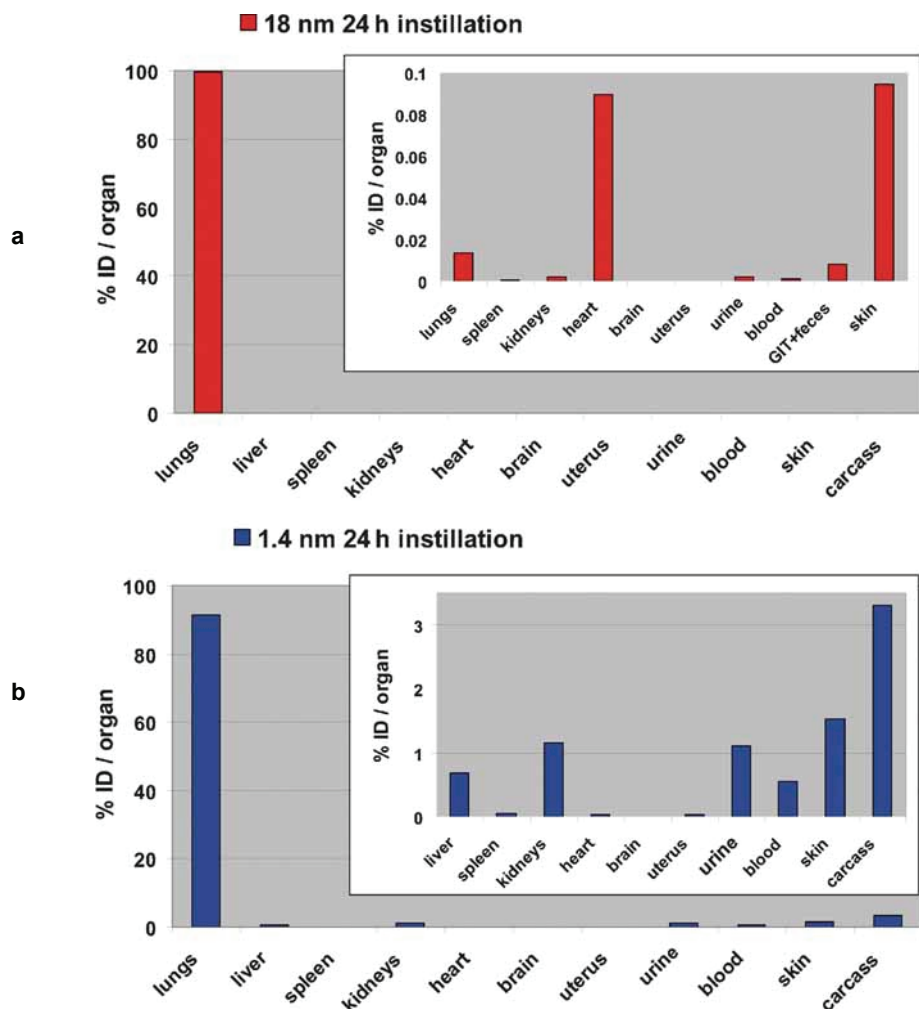


Figure 7: Biodistribution of 18 nm (a) and 1.4 nm (b) Au particles after intratracheal instillation
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This is a dramatic finding since it means that very small nanoparticles can be translocated through the air/blood barrier of the respiratory tract in significant amounts. The reason for the difference between 18 nm and 1.4 nm particles is to be seen in different transport mechanisms that are not yet understood in detail. These results should be of considerable public interest in context with the world-wide discussion on toxicity of fine dust.

References:

- [1] G. Schmid, *Chem. Soc. Rev.* **2008**, 37, Issue 9, 1745-2140. (Thematic issue dedicated to gold chemistry)
- [2] Y. Pan, A. Leifert, D. Ruau, S. Neuss, J. Bornemann, G. Schmid, W. Brandau, U. Simon, W. Jähnen Dechent, *Small*, submitted
- [3] M. Semmler-Behnke, W. G. Kreyling, J. Lipka, S. Fertsch, A. Wenk, S. Takenaka, G. Schmid, W. Brandau, *Small* **2008**, 4, 2108.

Recent Developments in Gold Catalysis

Rubén S. Ramón, Sylvain Gaillard and Steven P. Nolan*

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In the course of the past few years, the area of gold catalysis has experienced a veritable explosion of activity as its relevance to organic catalysis has been demonstrated. This “Gold Rush” has resulted in numerous publications on gold-mediated synthesis, frequent special journal issues and a number of reviews on the topic have appeared.¹ The ongoing interest in gold catalysis is due to the metal’s versatility and efficiency, covering a broad spectrum of transformations that is ever expanding. Having a retrospective look at gold-catalyzed chemistry, it is now clear that the mild Lewis acidic gold catalysts are excellent activators for various π -systems with an important emphasis on unsaturated C-C bonds.

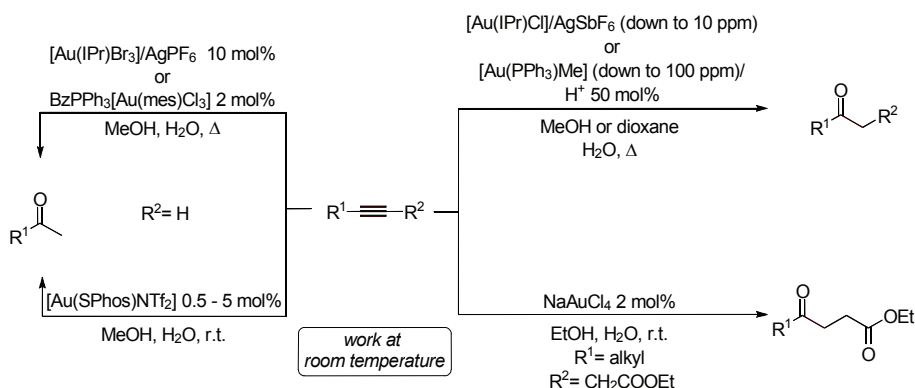
Although trivial Au (I) and Au(III) salts such as AuCl, AuCl₃ and NaAuCl₄ are often very useful and sufficient to catalyze a number of organic reactions, the advantages of employing gold catalysts bearing an ancillary ligand, e.g. the most common being [Au(PPh₃)Cl], are coming into focus. Supporting ligands not only improve the solubility of the metal but the nature of the ligand also affects reactivity and product selectivity. Although phosphines still represent the most important “players” in organometallic chemistry, recently, *N*-heterocyclic carbenes (NHCs) have been demonstrated as valuable alternatives to the dominant tertiary phosphine ligands in homogeneous catalysis. Conceptually addressed as tertiary phosphine mimic at the onset of their use in catalysis, NHCs have proven to possess advantageous characteristics. In gold NHC-based catalysis, complexes have displayed significant thermal stability and usually are not moisture and air sensitive. Recently, there have been efforts aimed at developing stable cationic gold complexes, the postulated active catalysts in gold(I) systems.² The NHC ligands have also permitted isolation of cationic gold(I) complexes. Additionally, Gagosz *et al.* reported the use of the weakly coordinating bis(trifluoromethanesulfonyl)imide instead of chloride as a stabilizing and yet reactive ligand.³ Both approaches eliminate the need for silver salt co-catalysts or activators to enable catalysis, rendering launching a reaction more straightforward and convenient. Some gold-NHC-based catalysts are even commercially available.

The present contribution offers a selection of recent examples using gold catalysis, provides a glimpse into the benefits associated with this catalysis and some of its implications in organic synthesis.

Hydration of alkynes and allenes

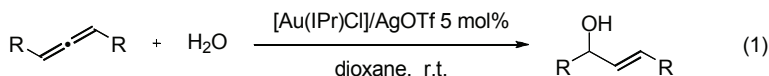
Being excellent π -systems activators, gold catalysts have mediated numerous organic reactions, including the gold-catalyzed hydration of alkynes. This transformation represents a convenient, environmentally friendly and atom economical protocol to

introduce a C-O bond into a molecule. While there are numerous reports on metal-based catalytic systems enabling this transformation, gold(I) has attracted attention in view of the mild reaction conditions leading to product formation. Au(III)-mediated alkyne hydration has also been reported, with emphasis on terminal alkynes. Catalysts facilitating this transformation now include NaAuCl_4 ,⁴ $\text{BzPPh}_3[\text{Au}(\text{mes})\text{Cl}_3]$ ⁵ and $[\text{Au}(\text{IPr})\text{Br}_3]$.⁶ In the later case, the reaction is limited to phenylacetylene derivatives. Of note, Au(I) catalysts appear to exhibit a broader substrate scope and allow lower catalyst loadings. While $[(\text{PPh}_3)\text{AuMe}]/\text{H}^+$ catalyzes alkyne hydration even at 100 ppm catalyst loading,⁷ the hydration can be performed under acid-free conditions, using as low as 10 ppm of $[\text{Au}(\text{IPr})\text{Cl}]/\text{AgSbF}_6$.⁸ Alternatively, Corma *et al.* reported very recently the use of 0.5-5 mol % $[\text{Au}(\text{SPhos})(\text{NTf}_2)]$ for the hydration of mostly terminal alkynes at room temperature.⁹ Concomitantly, Hammond *et al.* succeeded in the NaAuCl_4 -catalyzed hydration of β -keto esters at room temperature (reactions are summarized in Scheme 1).¹⁰



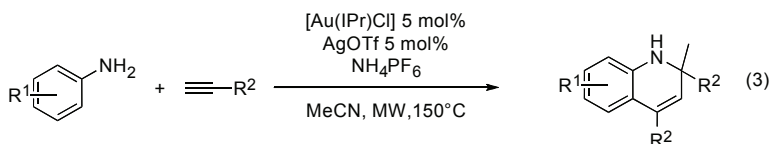
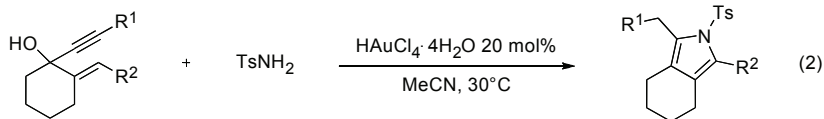
Scheme 1. Gold-catalyzed hydration of alkynes

In a logical extension of the hydration of alkynes work, Widenhoefer *et al.* reported on the hydration of allenes using $[\text{Au}(\text{IPr})\text{Cl}]/\text{AgOTf}$ to obtain (*E*)-allylic alcohols (eq.1).¹¹

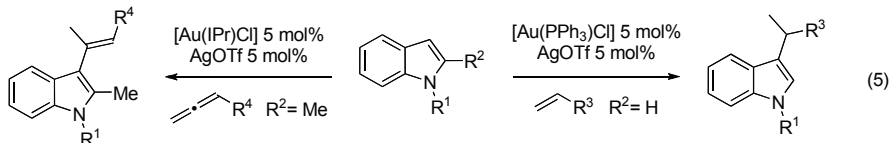
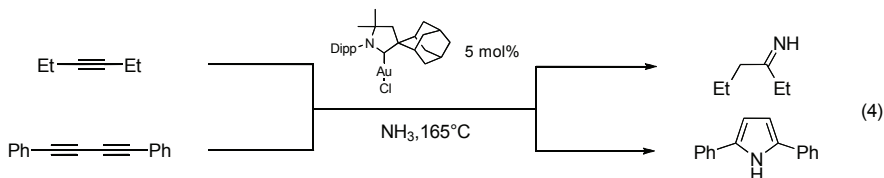


Hydroamination of alkynes and allenes

Gold can also catalyze the closely related hydroamination and hydroarylation reactions. Widenhoefer and co-workers, among others, have published on the use of gold-based catalysts for the hydroamination of alkynes,¹² allenes¹³ and alkenes.^{14,15} While the intramolecular hydroamination usually provides valuable *N*-heterocyclic compounds, intermolecular reactions present a convenient way to introduce nitrogen into a substrate. Liang *et al.* have reported a tandem amination/intramolecular hydroamination reaction catalyzed by Au(III) to easily afford highly substituted pyrroles¹⁶ (eq.2) whereas Che *et al.* disclosed the formation 1,2-dihydroquinolines by a tandem hydroamination/hydroarylation,¹⁷ starting from anilines and alkynes (eq.3).

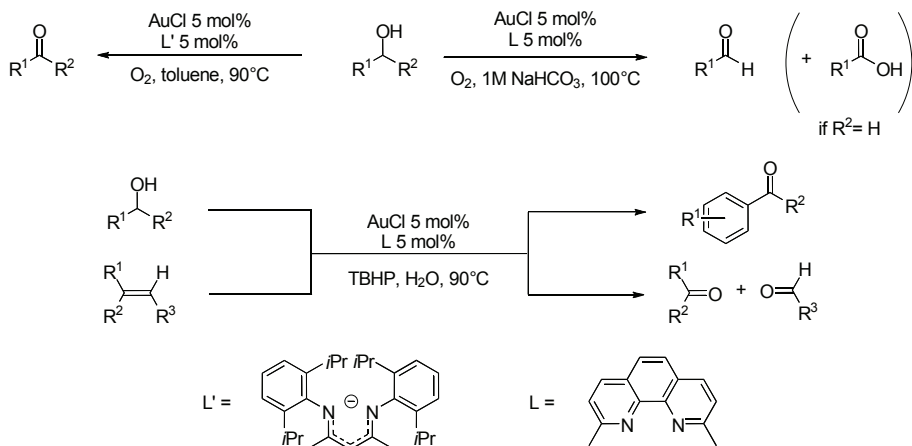


Very recently, Bertrand *et al.* succeeded in performing the hydroamination of alkynes and allenes with ammonia, a transformation for a long time ignored in homogeneous gold catalysis due to the formation of catalytically inactive Au-NH₃ complexes (eq.4).¹⁸ Recent examples of hydroarylation involving indoles with allenes and olefins have been reported by Widenhoefer¹⁹ and Che (eq.5).²⁰

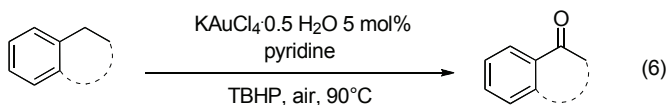


Oxidation reactions

Fewer studies have examined oxidation processes mediated by homogeneous gold species. Shi and co-workers have presented two Au(I) complexes, highly selective in the aerobic oxidation of various alcohols in aqueous media.^{21,22} The presence and pressure of oxygen appear to be crucial parameters in this reaction.

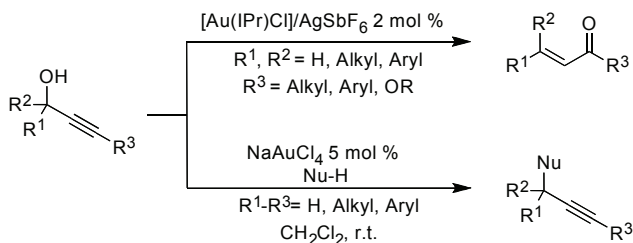


Scheme 2. Au^I-catalyzed oxidation of alcohols and oxidative cleavage of C=C bonds Shi *et al.* also reported the oxidative cleavage of olefins to form ketones and aldehydes.²³ (Scheme 2). In a recent contribution dealing with the Au(III)-catalyzed benzylic oxidation of alkanes into ketones, KAuCl₄ proved superior to the catalytically active AuCl/neocuproine system (eq.6).²⁴



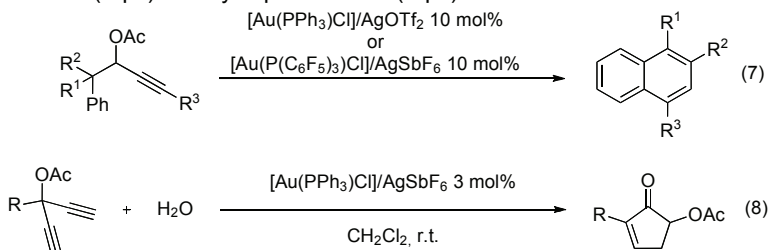
Reactions involving propargylic alcohol and its derivatives

Propargylic alcohol and its derivatives have attracted increasing interest as possible versatile substrates in homogeneous gold catalysis. One of these transformations, the Meyer-Schuster rearrangement,²⁵ is an efficient and atom economical methodology to obtain conjugated enones, presenting an attractive alternative to established methods such as the Horner-Wadsworth-Emmons reaction.²⁶ Several contributions have disclosed protocols for the gold-mediated Meyer-Schuster rearrangement. Dudley and co-workers have reported the preparation of α,β -unsaturated esters, by using electron-rich ethoxyacetylene and tertiary propargylic alcohols.²⁷ The use of electron-rich alkynes easily permits alkyne activation by a soft Lewis-acid catalyst such as AuCl₃ or AuCl. By activation of the alkyne, instead of the alcohol moiety, the competing Rupe rearrangement is inhibited.²⁸ The Au(I)-catalyzed Meyer-Schuster rearrangement was also reported by Chung²⁹ and more recently by Nolan and co-workers (Scheme 3, top).³⁰ Noteworthy, Akai disclosed a catalytic system applicable to primary alcohols by addition of [MoO₂(acac)₂] as co-catalyst.³¹ Campagne has recently provided a full account on the direct nucleophilic substitution of propargylic alcohols at room temperature using NaAuCl₄ as catalyst (Scheme 3, bottom).³² Investigations focusing on the reactivity of propargylic alcohols with 1,3-dicarbonyl compounds was recently described by Arcadi.³³

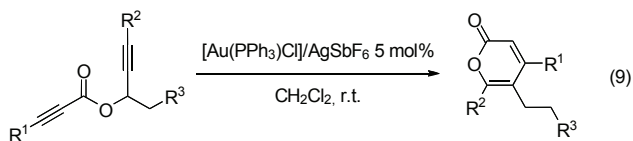


Scheme 3. Gold-catalyzed transformations of propargylic alcohols

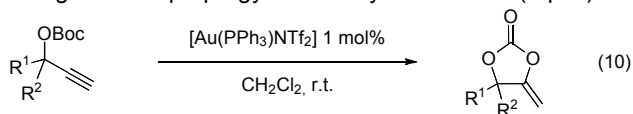
As these developments were appearing in print, propargylic esters emerged as a subject of considerable interest in gold catalysis. Usually, a 1,2- or 1,3- ester shift can be observed upon activation by gold. Interestingly, several transformations are induced through this internal rearrangement revealing new synthetic opportunities.³⁴ Nolan reported a tandem [3,3]-rearrangement/intramolecular hydroarylation providing indenenes in good yield.³⁵ Under aqueous conditions, conjugated enones were also obtained.³⁶ Zhang *et al.*³⁷ disclosed, concomitantly with Nolan, on the formation of conjugated enones, also reported the formation of α -iodoenones by the additional use of *N*-iodosuccinimide.³⁸ Amongst numerous reactions, propargylic esters have also proven useful in the formation of naphthalenes³⁹ (eq.7) and cyclopentenones (eq.8).⁴⁰



This rearrangement of propargylic esters has found applications in the synthesis of several sesquiterpenes as reported by Fürstner.⁴¹ Recently, Schreiber has also reported the formation of heterocyclic compounds such as α -pyrones obtained by a cascade reaction involving gold-mediated rearrangements (eq.9).⁴²

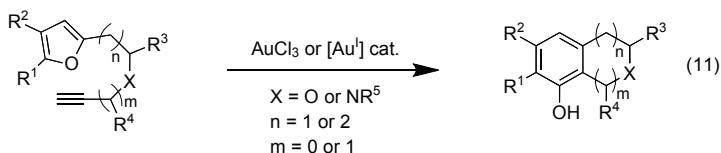


Interestingly, Schreiber used easily accessible diynes. The initial [3,3]-rearrangement is followed by the activation of the alkyne to yield the heterocycle. Gagosz has recently reported the rearrangement of propargylic *tert*-butyl carbonates (eq.10).⁴³



Phenol synthesis

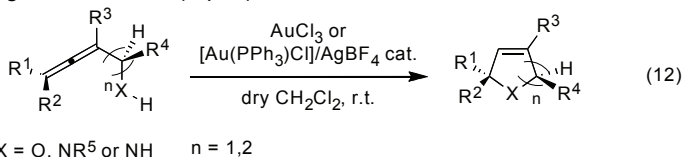
In gold catalysis, aromatic frameworks in the presence of an alkyne usually undergo a Friedel-Crafts-like cyclization. In spite of this general observation, Hashmi and co-workers have shown that alkynyl furans can be transformed into phenols (eq.11).⁴⁴ The most commonly used catalyst is AuCl_3 , however in some cases gold(I)⁴⁵ can also be employed. Recently, this reaction was extended to the synthesis of chromans, dihydrobenzofurans, dihydroindoles and tetrahydroquinolines from substrates containing furan with ynamide or ynol moieties in the side chain.⁴⁶



This reaction also found application in a domino reaction initiated by a gold(III)-catalyzed hydroarylation of electron-rich aromatic systems like furans, dimethoxybenzene and azulene on Michael acceptors such as ethynyl vinyl ketones.⁴⁷ In a first step, substrates furnished intermediates for a subsequent intramolecular cyclization leading to hydroxyindanones.^{44b,48} A second cascade reaction was also studied. The initial formation of a phenol was followed by an intramolecular attack on a second alkyne moiety to form highly substituted benzofurans.⁴⁹ This elegant phenol synthesis was used to generate a key intermediate in the synthesis of the sesquiterpene jungianol.^{44d} Finally, the analogous intermolecular reaction could also be achieved with 2,5-dimethylfuran and phenylacetylene.⁵⁰

Cycloisomerizations of allenenes

The cycloisomerization of α -hydroxyallenes and β -hydroxyallenes to obtain highly functionalized 2,5-dihydrofurans and dihydropyrans has been studied by Krause and co-workers.⁵¹ These reactions were achieved with complete axis to center chirality transfer. This cycloisomerization could be also extended to α -aminoallene,⁵² affording 3-pyrrolines and pyrrolidines with good stereoselectivity. β -aminoallene afforded the corresponding tetrahydropyridines. It should be noted that in the case of β -hydroxyallenes and β -aminoallene, among the various gold catalysts tested, best results were obtained with $\text{Au}(\text{PPh}_3)\text{Cl}/\text{AgBF}_4$ and AuCl_3 (eq.12).

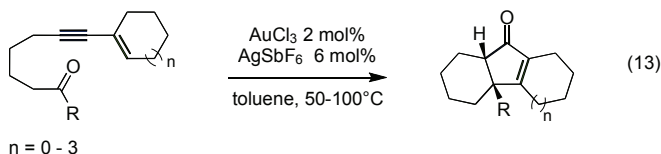


When the reaction was performed with AuBr_3 in the presence of *N*-iodosuccinimide, α -hydroxyallenes were converted into 3-iodo-2,5-dihydrofurans which could be re-engaged in a coupling reaction.⁵³ Recently, it was also demonstrated that ionic liquids are highly

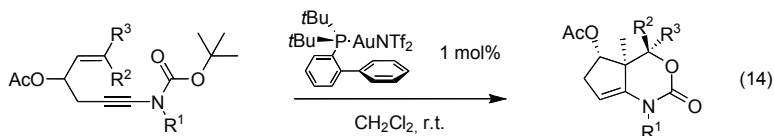
suitable for the cycloisomerization of α -hydroxyallenes.⁵⁴ The air stable $\text{AuBr}_3/[\text{BMIM}][\text{PF}_6]$ yielded highest conversions and showed very low catalyst release after extraction with hexane (0.03% after 5 runs). Finally, the cycloisomerization of α -hydroxyallenes and β -hydroxyallenes has proven useful in the synthesis of Furanomycin⁵⁵ and Bijarol.⁵⁶

Cycloisomerizations of 1,n-enynes and 1,n-allenynes

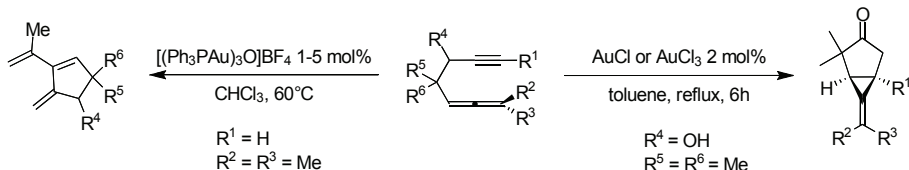
The cycloisomerization of 1,n-enynes and 1,n-allenynes is one of the most commonly studied reactions in gold catalysis. Here, we focus on recent advances on gold-catalyzed cycloisomerization of 1,3-, 1,4-, 1,5-, 1,6-enynes and allenynes.⁵⁷ Recently, an interesting report on a tandem heteroenyne metathesis⁵⁸ and Nazarov reaction was reported by Jin and Yamamoto⁵⁹ (eq.13). Precursors were conjugated enynes tethered to a ketone moiety to afford polycyclic enones using $\text{AuCl}_3/\text{AgSbF}_6$ as catalytic system.



Gagosz *et al.* reported a gold(I)-catalyzed transformation of *N*-(hex-5-enynyl) tert-butylcarbamates into functionalized bicyclic carbamates (eq.14).⁶⁰ A bicyclic compound was formed while up to two asymmetric centers could be created. However, the observed diastereoselectivity was low to moderate.



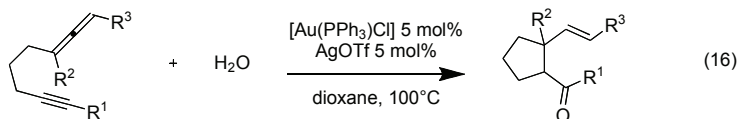
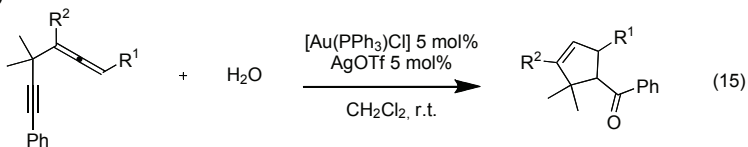
Gold catalysis involving 1,5-allenynes has hardly been investigated until recently. Toste and co-workers reported a Au(I)-catalyzed cycloisomerization of 1,5-allenynes into cross-conjugated trienes.⁶¹ In the case of allenynes bearing an alcohol at the propargylic position, Malacria, Fensterbank *et al.* have observed an allene transformation into 6-methylenebicyclo[3.1.0]hexan-3-one (Scheme 4).⁶² Very interestingly, $[\text{Au}(\text{PPh}_3)\text{Cl}]$ activated the allene instead of the alkyne moiety leading to a different outcome as that observed with PtCl_2 .



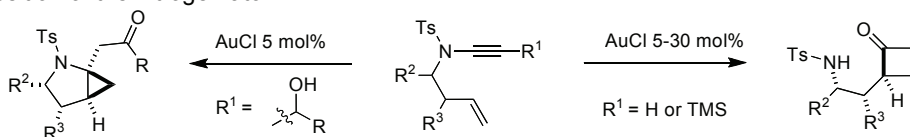
Scheme 4. Gold-catalyzed cycloisomerizations of 1,5-allenynes

Liu *et al.* reported a new hydrative cycloisomerization of 1,4- and 1,6-allenynes catalyzed by cationic gold(I) to produce, chemoselectively, cyclized ketones (eq.15 and 16).⁶³

Moreover, the use of chiral allenynes afforded the expected ketones with only minor loss of chirality.

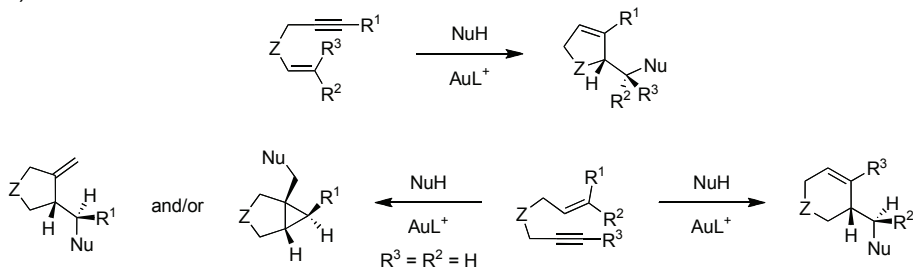


Cossy, Meyer and Couty recently studied the cycloisomerization of 1,6-enamides catalyzed by AuCl and AuCl₃.⁶⁴ Terminal- or trimethylsilyl-substituted ynamide frameworks afforded cyclobutanone derivatives, while ynamides bearing a propargylic alcohol yielded carbonyl compounds with a 2,3-methanopyrrolidine substituent (Scheme 5). Noteworthy is the high diastereoselectivity observed in the presence of a stereo-center in the α or β position of the nitrogen atom.



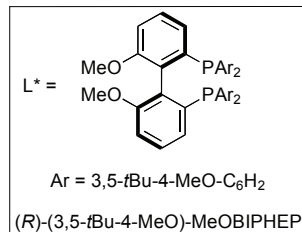
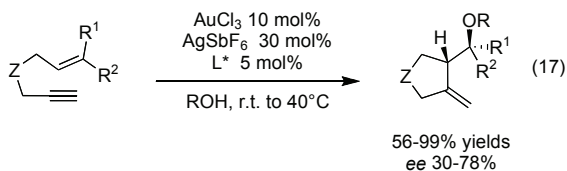
Scheme 5. Gold-catalyzed cycloisomerizations of 1,6-enamides

In the context of the gold-catalyzed cycloisomerization of 1,5- and 1,6-enynes in the presence of a nucleophile, Echavarren^{2b} and Michelet⁶⁵ have shown that electron-rich aromatic rings such as methoxy substituted benzenes, indoles, pyrroles, furans, 1,3-dicarbonyl fragments and allylsilanes lead to carbo- and heterocyclic compounds (Scheme 6).



Scheme. 6 Gold-catalyzed cycloisomerizations of 1,5- and 1,6-enynes in presence of nucleophiles

Michelet and co-workers have also developed an asymmetric version of this reaction using bidentate phosphorus ligand. The best results were obtained with (*R*)-4-MeO-3,5-(*t*Bu)₂-MeOBIPHEP (eq. 17).⁶⁶



In summary, with the recent highlighted examples we hope to have raised the Reader's attention to this exciting chemistry and convinced him/her that gold catalysis represents a quite versatile tool in organic chemistry. The soft Lewis acidity character of gold complexes and their ability to activate various π -systems qualifies them for a plethora of useful reactions, including applications in total synthesis. Furthermore, many gold catalysts are stable to air and moisture, making them very convenient. Finally, gold complexes often permit the use of low catalyst loading and mild reaction conditions thereby contributing to atom-economical and environmentally friendly chemical transformations.

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Capabilities of AUROLite™ Catalysts

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AUROLite™ catalysts (1wt%gold on titania, alumina and zinc oxide supports) are made in kilogram quantities by Project AuTEK and their advantages over other precious metal catalysts are being demonstrated by achieving high activities and selectivities in both liquid- and gas-phase reactions which have commercial potential.

1. Introduction

Gold catalysts are very active under the mild conditions which favour their selectivity and the economics of the processes involved. Careful choice of preparative conditions and supports helps to maximize their selectivity and activity [1]. Their potential in chemical processing reactions has been clearly demonstrated and there is definite evidence of increasing R&D involving gold and gold-platinum group metal (PGM) combinations [2]. This is likely to result in new industrial applications for gold catalysts in chemical processing and pollution control. Selective oxidation of carbon monoxide in the hydrogen streams used for fuel cells has been achieved using AuTEK catalysts, as is the use of this ambient temperature oxidation process for use in gas masks for protection from CO poisoning and for CO removal from room atmospheres [2,3]. AuTEK has produced three gold catalyst systems, and use of these catalysts, and other closely related gold catalysts to optimize requirements for particular reactions where high activity or selectivity to desirable products is required, is indicated below.

2. Gas Phase Reactions

AUROLite™ catalysts have been evaluated for their CO oxidation characteristics at Oak Ridge National Laboratories, USA [4]. The Au/TiO₂ catalyst gave 100% conversion of CO at < 0 °C and the Au/Al₂O₃ catalyst was also very active at low temperatures. All three AUROLite™ catalysts are being developed by Project AuTEK for CO oxidation in respiratory protection devices [5]. As can be seen in Figure 1, under typical EN403 (fire escape mask) test conditions the Au/TiO₂ is more active and durable than the established commercial technology namely Hopcalite (CuMnOx). Furthermore under these conditions the activity of this material is amplified by the presence of moisture, unlike Hopcalite which experiences rapid deactivation.

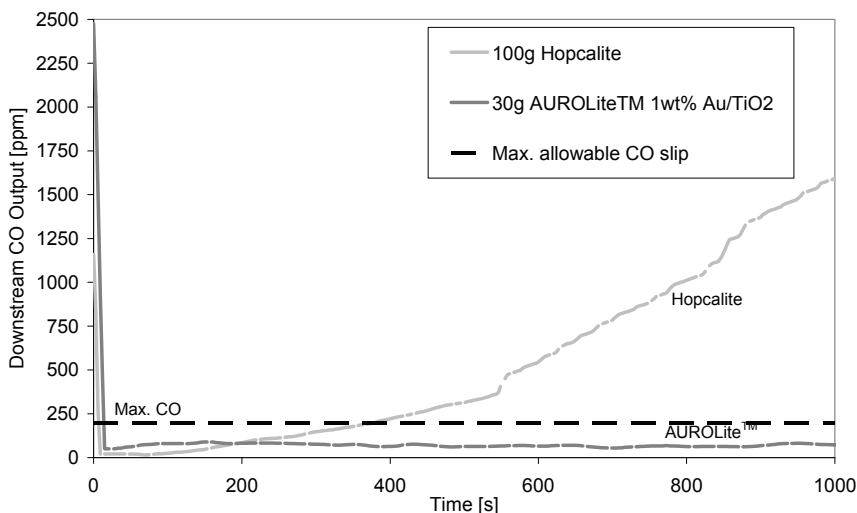
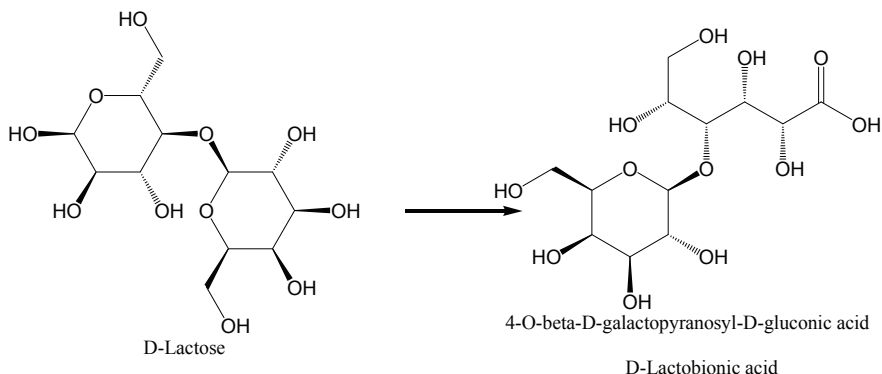


Figure 1 : EN403 Simulation, feed = 2500ppm CO in air, 90%RH, 30LPM, constant flow, bed = 4.7cm diameter, particle size 1 - 2mm.

The AUROLite™ Au/TiO₂ catalyst has been used for the oxidation of CO and H₂ by O₂ and N₂O by a group from the Technical University of Denmark, Lyngby [6]. This group also studied the low temperature oxidation of methane on AUROLite™ catalysts and found them active and stable with very little sintering up to 250°C [7]. The catalysts have also been shown to give complete conversion of propene at 250 – 350°C (i.e. VOC removal) and the gold particles do not sinter under these conditions either [8]. The alumina and zinc oxide catalysts give high conversions in methanol oxidation [9]. In addition, all three catalysts are currently being assessed for water-gas shift and selective hydrogenation activity.

Gas phase selectivity of gold catalysts has been confirmed in an unconventional PROX system, where the complete removal of CO from 'dirty' hydrogen (i.e. down to < 1ppm CO from up to 2000 ppm). For use in a fuel cell, the carbon monoxide still present in the hydrogen, obtained by water-gas shift or from other sources, must be removed to prevent it poisoning the platinum electro-catalyst inside the fuel cell. Gold catalysts have been found to be effective for this preferential oxidation reaction. Whereas PGM catalysts oxidize both the CO and the hydrogen, gold is selective for CO at close to ambient temperatures. This has enabled Project AuTEK to develop a new system for hydrogen purification for PEM fuel cells, trade named AUROPureH₂™ based on the use of a 3wt%Au/TiO₂ catalyst used at room temperature [10].

3. Liquid Phase Reactions



Following their successful use in the oxidation of glucose to gluconic acid, the conversion of D-lactose to D-lactobionic acid (LBA) has been studied using Project AuTEK catalysts.

Results obtained using samples of the three AuTEK gold catalysts show that all of these materials produce high selectivity for LBA under mild conditions [11]. It has been found, however, that the activities vary with support type, with the 1wt%Au/ZnO catalyst being the most reactive, as indicated in Table 1:

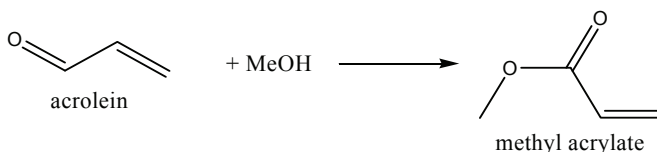
Table 1 : Support effects in the oxidation of D-lactose to D-lactobionic acid

	0.8%Au/Al ₂ O ₃	1%Au/TiO ₂	1%Au/ZnO
M x t _{20%} (g _{Au} min)	9.12	7.4	5.6
Selectivity (%)	94.3	95.1	93.9

C₀=99.6 mmol l⁻¹, 0.2 g_{cat}, T = 60 °C, pH=8, O₂=2.5ml min⁻¹, results adapted from ref 11.

*time in minutes to reach 20% conversion

AuTEK catalysts have also been used to catalyse the aerobic oxidation of aldehydes to esters, e.g. the conversion of acrolein to methyl acrylate [12]:



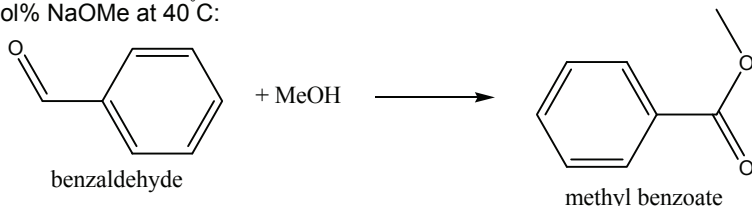
Methyl acrylate is used in the manufacture of paints, in solvents and for acrylate coatings. This reaction proceeds in methanol using air as oxidant at room temperature, and therefore has the appeal of being 'green' chemistry. The high conversions and selectivities are indicated in Table 2.

Table 2 : Synthesis of methyl acrylate from acrolein using 1wt% Au/TiO_2 AuTEK catalyst

Time (h)	1	4	20
Conversion (%)	46	75	97
Selectivity (%)	43	66	87

Acrolein:Methanol 1:80, 0.3 mol % 1wt % Au/TiO_2 , T = 25°C, results adapted from ref 12.

In addition, the use of AuTEK catalysts has been studied for the reaction between benzaldehyde and methanol to produce methyl benzoate [12], which has a pleasant odour and is used in perfumes. 100% conversion was obtained in ca. 20 min when the benzoic acid:methanol ratio was 1:30 in the presence of 0.2 mol% 1wt% Au/TiO_2 AuTEK catalyst and 10mol% NaOMe at 40°C:



Other reaction types for which AUROLite™ catalysts are being investigated include glucose and glycerol oxidation, direct hydrogen peroxide synthesis and hydrodechlorination of water contaminants such as trichloroethene.

4. Conclusions

Gold catalysts are likely to make a large and unique contribution to applications where efficient chemical processes of the kind described herein are required under mild energy-efficient conditions, as is adequately indicated by the examples obtained using AuTEK catalysts and related work described in recent literature.

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- [5] D.Ramdayal, J. McPherson, T. Khumalo, G. Patrick and E. van der Lingen, Proc. GOLD 2009, Heidelberg, Germany, July 2009.
- [6] G. Walther, D.J. Mowbray, T. Jiang, G. Jones, S. Jensen, U.J. Quaade and S. Horch, *J. Catal*, 2008, **260**, 86.
- [7] G. Walther, L. Cervera-Gontard, U. Quaade and S. Horch, *Gold Bull*, 2009, in press
- [8] L.F. Liotta, G. Pantaleo, G. Di Carlo, A.M. Venezia, G. Dagenallo, M. Ousmane, A. Giroir-Fendler and L. Retailleau, Proc. 'Catalysis for Society' Conference, Krakow, Poland, May 2008.
- [9] M. Ziolk, Paper to be presented to 6th World Conference on Oxidation Chemistry, Lille, France, July 2009.
- [10] J. Steyn, G. Patrick, E. van der Lingen, M. Scurrall and D. Hildebrandt, *South African Patent Appl.*, 2006, 1120.
- [11] E.V. Murzina, A.V. Tokarev, K. Kordas, H. Karhu, J.-P. Mikkloa and D.Y. Murzin, *Catal Today*, 2008, **131**, 385.
- [12] C.Marsden, E.Taarning, D.Hansen, L.Johansen, S.K.Klitgaard, K.Egeblad , C.H.Christensen, *Green Chem*, 2008, **10**, 168, and private communication.

New Products Introduced Since Catalog 22

GOLD AUROlite™ Catalysts

79-0160 Gold 1% on aluminum oxide extrudates (AUROlite™ Au/Al₂O₃) 10g
NEW→ dark purple extrudates ~1.2mm dia. x 5mm (avg) (*store cold*) 50g

Analysis: Au 1 wt% ± 0.1%
 Al₂O₃ 98 wt%
 Na⁺, Cl⁻ <1500ppm

Bulk density: 0.6–0.8 g/ml
 Specific surface area: 200–260 m²/g

Note: Sold in collaboration with Project AuTEK for research purposes. Reverse engineering and product modification prohibited. Only open before use, store cold in dark. See web for more details.

Technical Note:

- Useful product for the catalytic oxidation of a variety of substrates including carbon monoxide, aldehydes, alkenes and methane. Average gold crystallite size is ~2-3nm.

References:

- J. Catal.*, **2007**, 252, 119.
- J. Catal.*, **2008**, 260, 86.
- Green Chem.*, **2008**, 10, 168.
- Gold Bulletin*, **2008**, 41, 296.

79-0165 Gold 1% on titanium dioxide extrudates (AUROlite™ Au/TiO₂) 10g
NEW→ dark purple/gray extrudates 1.5mm dia. x 5mm (avg) (*store cold*) 50g

Analysis: Au 1 wt% ± 0.1%
 TiO₂ 98 wt%
 Na⁺, Cl⁻ <1500ppm

Bulk density: 0.85–0.95 g/ml
 BET (surface area): 40–50 m²/g

Note: Sold in collaboration with Project AuTEK for research purposes. Reverse engineering and product modification prohibited. Only open before use, store cold in dark. See web for more details.

Technical Note:

- Useful product for the catalytic oxidation of a variety of substrates including carbon monoxide, aldehydes, alkenes and methane. Average gold crystallite size is ~2-3nm.

References:

- J. Catal.*, **2007**, 252, 119.
- J. Catal.*, **2008**, 260, 86.
- Green Chem.*, **2008**, 10, 168.
- Gold Bulletin*, **2008**, 41, 296.

79-0170 Gold 1% on zinc oxide granulate (AUROlite™ Au/ZnO) 10g
NEW→ dark purple granulate 1-2mm dia. (*store cold*) 50g

Analysis: Au 1 wt% ± 0.1%
 ZnO 88 wt% (contains Al₂O₃)
 Na⁺, Cl⁻ <1500ppm

Bulk density: 1–1.2 g/ml
 BET (surface area): 40–50 m²/g

Note: Sold in collaboration with Project AuTEK for research purposes. Reverse engineering and product modification prohibited. Only open before use, store cold in dark. See web for more details.
 PCT WO2005115612.

Technical Note:

- Useful product for the catalytic oxidation of a variety of substrates including carbon monoxide, aldehydes, alkenes and methane. Average gold crystallite size is ~2-3nm.

References:

- J. Catal.*, **2007**, 252, 119.
- J. Catal.*, **2008**, 260, 86.
- Green Chem.*, **2008**, 10, 168.
- Gold Bulletin*, **2008**, 41, 296.

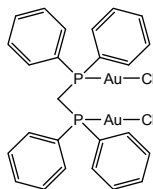
GOLD (Elemental forms)

79-0060	Gold foil (99.95%) [7440-57-5] 0.1mm thick (~1.2g/25mm x 25mm)	25 x 25mm 50 x 50mm
79-0050	Gold foil (99.9%) [7440-57-5] 0.01mm thick (~0.12g/25mm x 25mm)	25 x 25mm 50 x 50mm
93-7915	Gold powder (99.95%) [7440-57-5] 2-5 micron	500mg 2g
93-7912	Gold powder (99.9+%) [7440-57-5] 1.5-3.0 micron spherical	500mg 2g
93-7902	Gold powder (99.999%) [7440-57-5] -20 mesh	500mg 2g
93-7913	Gold shot (99.95%) [7440-57-5] 6.35 mm and down, semi-spherical	500mg 2g
79-0075	Gold shot (99.9999%) [7440-57-5] 0.8-6 mm	500mg 2.5g
79-0080	Gold/tetra-n-octylammonium chloride colloid SEE GOLD NANOMATERIALS SECTION (page 34)	
79-0090	Gold wire (99.9999%) [7440-57-5] 1.4mm dia. (~0.6g/2cm)	2cm 10cm

GOLD (Compounds)

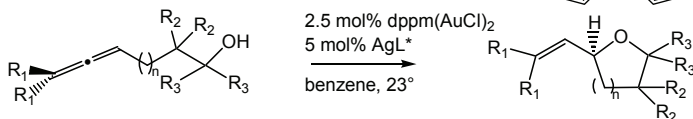
02-1000	Ammonium tetrachloroaurate(III) hydrate (99.9985%-Au) PURATREM [13874-04-9] $\text{NH}_4\text{AuCl}_4 \cdot \text{XH}_2\text{O}$; FW: 356.82; yellow xtl.	1g 5g
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79-0115 NEW→	[μ-Bis(diphenylphosphino)methane] dichlorodigold(I), 99% [37095-27-5] $\text{C}_{25}\text{H}_{22}\text{Au}_2\text{Cl}_2\text{P}_2$; FW: 849.23; white powdr.	250mg 1g
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Technical Note:

1. Catalyst used with chiral counterion for asymmetric hydroalkoxylation.



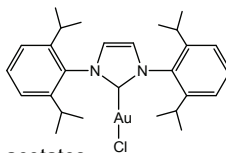
Ref. (1)

Reference:

1. *Science*, **2007**, 317, 496.

n=1,2 90%, 99% ee

79-0200 NEW→	1,3-Bis(2,6-di-isopropylphenyl) imidazol-2-ylidene gold(I) chloride, 95% [852445-83-1] $\text{C}_{27}\text{H}_{36}\text{AuClN}_2$; FW: 621.01; white powdr.	250mg 1g
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Technical Notes:

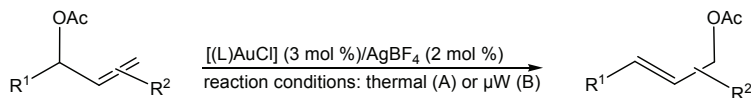
1. Catalyst used for the rearrangement of allylic acetates.
2. Catalyst used for alkane carbon-hydrogen bond functionalization.
3. Catalyst used for room temperature hydroamination of N-alkenyl ureas.
4. Catalyst used for the acid-free hydration of alkynes at low loadings.

GOLD (Compounds)

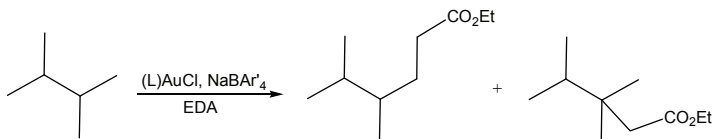
79-0200 1,3-Bis(2,6-di-isopropylphenyl)imidazol-2-ylidene gold(I) chloride, 95% [852445-83-1]

(cont.)

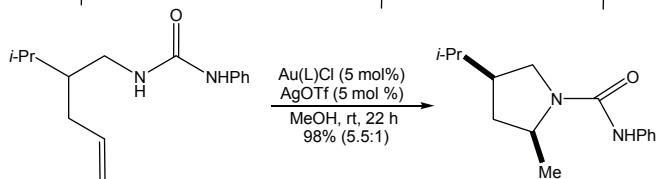
NEW→



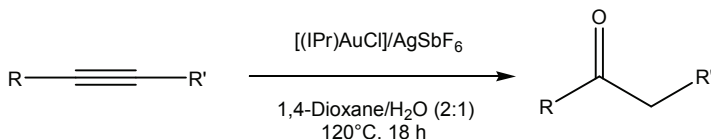
Tech. Note (1)
Ref. (1)



Tech. Note (2)
Ref. (2)



Tech. Note (3)
Ref. (3)



Tech. Note (4)
Ref. (4)

References:

1. *Org. Lett.*, 2007, 9, 2653.
2. *Organometallics*, 2006, 25, 2237.
3. *Org. Lett.*, 2006, 8, 5303.
4. *J. Am. Chem. Soc.*, 2009, 131, 448.

79-0350 Chlorocarbonyl gold(I), min. 97% [50960-82-2]

Au(CO)Cl; FW: 260.43; off-white powdr.

air sensitive, moisture sensitive, (store cold)

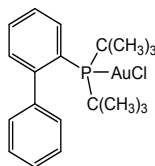
1g

5g

79-0340 Chloro[2-(di-*t*-butylphosphino)

biphenyl]gold(I), 99% [854045-93-5]

C₂₀H₂₇AuClP; FW: 530.82; white powdr.

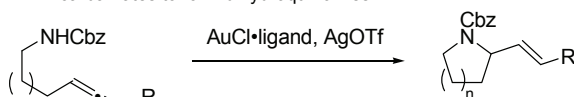


250mg

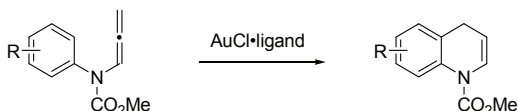
1g

Technical Notes:

1. Catalyst for the intramolecular hydroamination of allenes.
2. Catalyst for the intramolecular cyclization of allenyl carbamates to form dihydroquinolines.



Tech. Note (1)
Ref. (1)



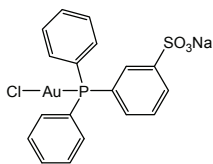
Tech. Note (2)
Ref. (2)

References:

1. *J. Am. Chem. Soc.*, 2006, 128, 9066.
2. *Org. Lett.*, 2007, 9, 4821.

GOLD (Compounds)

79-1100 Chloro[diphenyl(3-sulfonatophenyl)phosphine]gold(I), sodium salt, min. 98% 250mg
 1g
 $\text{AuCl}[(\text{C}_6\text{H}_5)_2\text{P}(\text{C}_6\text{H}_4\text{SO}_3\text{Na})]$;
 FW: 596.75; white to off-white powdr.
light sensitive

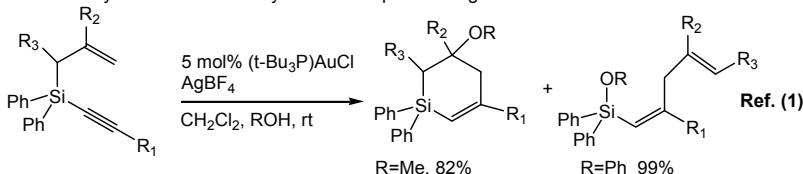


Technical Note: Water soluble gold complex.

79-0740 Chlorotri-*t*-butylphosphinegold(I), 99% [69550-28-3] 250mg
 AuClP(C₄H₉)₃; FW: 434.74; white microxtl. 1g

Technical Note:

1. Catalyst used for the acetylenic sila-Cope rearrangement.



Reference:

1. *J. Am. Chem. Soc.*, **2006**, 128, 11364.

79-0750 Chlorotriethylphosphine gold(I), 99% [15529-90-5] 250mg
 HAZ AuClP(C₂H₅)₃; FW: 350.57; white to pink xtl.; m.p. 85-87° 1g
 5g

79-0850 Chlorotrimethylphosphine gold(I), min. 98% [15278-97-4] 500mg
 AuClP(CH₃)₃; FW: 308.49; white xtl.; m.p. 225-228° 2g

79-1000 Chlorotriphenylphosphine gold(I), 98+% (99.9+%-Au) [14243-64-2] 250mg
 AuClP(C₆H₅)₃; FW: 494.71; white xtl. 1g
 5g

79-1500 Dimethyl(acetylacetonate)gold(III), 98% (99.9%-Au) [14951-50-9] 500mg
 (CH₃)₂(C₅H₇O₂)Au; FW: 326.60; white to off-white xtl.; m.p. 81-82°; 2g
 b.p. subl. ~25°/0.01mm
(store cold)

Technical Notes:

1. Highly volatile gold source for MOCVD applications. Must ship overnight in dry ice.
2. Precursor for synthesis of gold nanoparticles. Au/ZrO₂ and Au/Al₂O₃ prepared in this way were extremely efficient catalysts for the aerobic oxidation of glucose. (Ref. 1)

Reference:

1. *Angew. Chem. Int. Ed.*, **2008**, 47, 9265.

79-1600 Dimethyl(trifluoroacetylacetonate)gold(III), 98% (99.9%-Au) [63470-53-1] 500mg
 HAZ (CH₃)₂Au(CF₃COCHCOCH₃); FW: 380.12; 2g
 white to off-white xtl.
air sensitive, heat sensitive, light sensitive, (store cold)

Technical Note:

1. Highly volatile gold source for MOCVD applications. Must ship overnight in dry ice.

79-2015 Diphenyl(m-sulfonatophenyl)phosphine-gold nanocluster (water soluble)
 (1-3 nm) 500mg
 NEW→ SEE GOLD NANOMATERIALS SECTION (page 30)

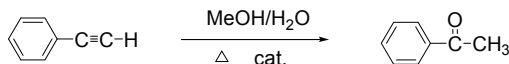
93-7905 Gold(III) bromide, anhydrous, 99% (99.9+%-Au) [10294-28-7] 1g
 HAZ AuBr₃; FW: 436.69; orange to brown powdr. 5g

GOLD (Compounds)

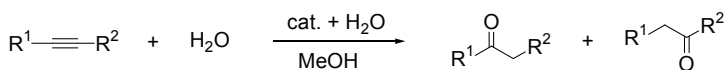
79-1900	Gold(I) chloride, 97% (99.99%-Au) PURATREM [10294-29-8] AuCl; FW: 232.42; yellow powdr.; m.p. 289° dec.; d. 7.4	250mg 1g 5g
93-7907	Gold(III) chloride, 99% (99.9%-Au) [13453-07-1] AuCl ₃ ; FW: 303.33; maroon xtl.; m.p. 254° dec.	250mg 1g 5g
93-7901 HAZ	Gold(I) cyanide (99.9%-Au) [506-65-0] AuCN; FW: 222.98; yellow powdr.; d. 7.12	1g 5g
79-2000	Gold(I) iodide, 99% (99.9+%-Au) [10294-31-2] AuI; FW: 323.87; yellowish-green powdr.; m.p. 120° dec.; d. 8.25 (store cold)	1g 5g
93-7903	Gold(III) oxide, 99% [1303-58-8] Au ₂ O ₃ ; FW: 441.93; orange to brown powdr.; m.p. dec.	1g 5g
79-2150 HAZ	Hydrogen tetrabromoaurate(III) hydrate (99.9%-Au) [17083-68-0] HAuBr ₄ ·XH ₂ O; FW: 517.61; black xtl. <i>moisture sensitive</i>	1g 5g
79-0500 HAZ	Hydrogen tetrachloroaurate(III) hydrate (99.9%-Au) (49% Au) (Chloroauric acid) [16903-35-8] HAuCl ₄ ·XH ₂ O; FW: 339.79; yellow to orange xtl. <i>light sensitive, hygroscopic, (store cold)</i>	1g 5g 25g
79-2200 HAZ	Hydrogen tetrachloroaurate(III) hydrate (99.9985%-Au) (49% Au) PURATREM [16903-35-8] HAuCl ₄ ·XH ₂ O; FW: 339.79; yellow to orange xtl. <i>light sensitive, hygroscopic, (store cold)</i>	1g 5g
79-5000	Methyl(triphenylphosphine)gold(I), 99% [23108-72-7] Au(CH ₃)P(C ₆ H ₅) ₃ ; FW: 474.29; white xtl.	250mg 1g

Technical Notes:

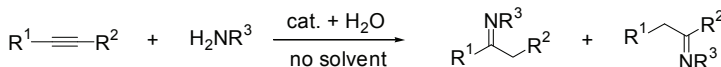
1. Catalyst used for the addition of water to alkynes.
2. Highly efficient catalyst for the intermolecular hydroamination of alkynes.



Tech. Note (1)
Ref. (1)



Tech. Note (1)
Ref. (2)



Tech. Note (2)
Ref. (3)

References:

1. *J. Am. Chem. Soc.*, **2003**, 125, 11925.
2. *Angew. Chem. Int. Ed.*, **2002**, 41, 4563.
3. *Org. Lett.*, **2003**, 5, 3349.

79-3000 HAZ	Potassium dicyanoaurate(I), 99% [13967-50-5] KAu(CN) ₂ ; FW: 288.10; white powdr.	1g 5g
79-3250	Potassium tetrabromoaurate(III) dihydrate, 99% [14323-32-1] KAuBr ₄ ·2H ₂ O; FW: 555.71 (591.74); reddish-brown xtl.	1g 5g
93-7906	Potassium tetrachloroaurate(III) hydrate [13682-61-6] KAuCl ₄ ·XH ₂ O; FW: 377.88; yellow to orange xtl.	1g 5g

GOLD (Compounds)

79-3505	Sodium tetrabromoaurate(III) hydrate (99.9+%-Au) [52495-41-7] NaAuBr ₄ ·XH ₂ O; FW: 539.59; red to black xtl.	1g 5g
79-3590 NEW→	Trichloropyridinegold(III), min. 97% [14911-01-4] (C ₅ H ₅ N)AuCl ₃ ; FW: 382.43; pale yellow powdr.	250mg 1g

79-3610 NEW→	Triphenylphosphinegold(I) trifluoromethanesulfonate, min. 98% [156397-47-6] [(C ₆ H ₅) ₃ PAu] ⁺ CF ₃ SO ₃ ⁻ ; FW: 608.23; white to off-white powdr. <i>air sensitive</i>	250mg 1g
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Technical Notes:

Versatile catalyst for a wide variety of organic transformations.

1. Glycosidation of 1,2-anhydrosugars.
2. Direct carbocyclization of aldehydes with alkynes.
3. Hydroamination of alkenes.
4. Rearrangement of propargylic alcohols to unsaturated ketones.
5. Hydroamination of 1,3-dienes.

References:

1. *J. Org. Chem.*, **2008**, 73, 4323.
2. *Org. Lett.*, **2008**, 10, 1025.
3. *Org. Lett.*, **2006**, 8, 2707.
4. *Synthesis*, **2007**, 14, 2107.
5. *Angew. Chem. Int. Ed.*, **2006**, 45, 1744.

79-3600	Tris[triphenylphosphinegold(I)]oxonium tetrafluoroborate, 98% [53317-87-6] [(C ₆ H ₅) ₃ PAu] ₃ O ⁺ BF ₄ ⁻ ; FW: 1480.56; off-white powdr.; m.p. 207° dec. <i>air sensitive</i>	250mg 1g
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GOLD NANOMATERIALS

79-2015 NEW→	Diphenyl(m-sulfonatophenyl)phosphine-gold nanocluster (water soluble) (1-3 nm) dark red solid; particle size: 1-3 nm Note: Made to order. Long term shelf life not established.	100mg 500mg
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79-0134 NEW→	Gold Nanochain [AuNP-Chain: 1-2 µm (Gum Arabic)] maroon-red liq.	25ml
Properties: Water soluble, stable at pH 7.0 Color: Maroon-Red Shape: Chain Stability: Stable for 90 days Chain length: 1-2 µm UV-Vis (nm): 760 nm Size: 7 ± 3nm Ordering Specifications : Minimum 2 weeks required to process the order. •Supplied in aqueous solutions. Contains gum arabic stabilizer. •Suitable for spin coating, self-assembly and monolayer formation. •Sensor design, nanoelectronics and MEMS applications.		

79-0146 NEW→	Nanoparticle Embedded Sheets [AuNP-Embedded in Agarose Sheets (2x2cm)] maroon-red sheets	5pc
Properties: Water soluble, stable at pH 7.0 Color: Maroon-Red Shape: Sphere Ratio: 12 nm UV-Vis (nm): 540 nm Ordering Specifications: Minimum 2 weeks required to process the order. •Supplied in sheets. Contains Agarose stabilizer. •Suitable for spin coating, self-assembly and monolayer formation. •Sensor design, nanoelectronics and MEMS applications.		

GOLD NANOMATERIALS

79-6040 NEW→	Spherical Gold Nanoparticles (30 nm) violet liq.	5ml 25ml
	Color and Form: violet liq.	Concentration: 0.03mg/ml (±10%)
	Storage Conditions: store at ~4°C (do not freeze)	
	Shelf Life: 6 months	

79-6045 NEW→	Spherical Gold Nanoparticles (50 nm) red liq.	5ml 25ml
	Color and Form: red liq.	Concentration: 0.03mg/ml (±10%)
	Storage Conditions: store at ~4°C (do not freeze)	
	Shelf Life: 6 months	

79-6050 NEW→	Spherical Gold Nanoparticles (70 nm) red liq.	5ml 25ml
	Color and Form: red liq.	Concentration: 0.03mg/ml (±10%)
	Storage Conditions: store at ~4°C (do not freeze)	
	Shelf Life: 6 months	

79-6055 NEW→	Spherical Gold Nanoparticles (90 nm) pink liq.	5ml 25ml
	Color and Form: pink liq.	Concentration: 0.03mg/ml (±10%)
	Storage Conditions: store at ~4°C (do not freeze)	
	Shelf Life: 6 months	

96-1540 NEW→	Spherical Gold Nanoparticles Kit (30-90 nm)	1 kit
	Contains 25ml unit of each of the following:	

79-6040	Spherical Gold Nanoparticles (30 nm)
79-6045	Spherical Gold Nanoparticles (50 nm)
79-6050	Spherical Gold Nanoparticles (70 nm)
79-6055	Spherical Gold Nanoparticles (90 nm)

79-0150 NEW→	Sticky-Gold Nanoparticles [AuNP: 30-35 nm] maroon-red liq.	5ml
	Properties: Water soluble	
	Size: 30-35nm	
	Color: Maroon-Red	UV-Vis (nm): 535 nm
	Shape: Sphere	
	Stability: Stable for 60 days in aqueous media.	
	•"One-step" direct labeling of gold nanoparticles with proteins, peptides or various biomarkers.	
	•Supplied in aqueous solutions . Readily reacts with disulfide group in biomolecules.	
	•In vitro diagnostics.	

79-0118 NEW→	Sugar Coated Gold Nanoparticles [AuNP: 22-38 nm (Glucose)] maroon-red liq.	5ml
	Properties: Water soluble	
	Color: Maroon-Red	Size: 22-38, 4-16, 6-10 or 1-2 nm
	Shape: Sphere	UV-Vis (nm): 535, 535, 540 or 540 nm
	Stability: Stable for 1 day.	
	• Supplied as kit.	
	•Suitable for in vitro use and sensor design applications.	

79-0124 NEW→	Sugar Coated Gold Nanoparticles [AuNP: 1-2 nm (Lactose)] maroon-red liq.	5ml
	Technical Note:	
	1. See 79-0118 (page 31).	

GOLD NANOMATERIALS

79-0122 **Sugar Coated Gold Nanoparticles [AuNP: 6-10 nm (Maltose)]** 5ml

NEW→

maroon-red liq.

Technical Note:

1. See 79-0118 (page 31).

79-0120 **Sugar Coated Gold Nanoparticles [AuNP: 4-16 nm (Sucrose)]** 5ml

NEW→

maroon-red liq.

Technical Note:

1. See 79-0118 (page 31).

79-0136 **Gold Nanorods [AuNP-Rod: Aspect Ratio: 3-3.5 (CTAB)]** 5ml

NEW→

maroon-red liq.

Properties: Water soluble

Color: Maroon-Red

Shape: Rod

Stability: Stable for 14 days

•Supplied in aqueous solutions. Contains CTAB stabilizer.

•Ready for biomolecule conjugation.

•Suitable for in vitro use and sensor design applications.

Aspect Ratio: 3-3.5

UV-Vis (nm): 680 nm

79-6000 **Gold Nanorods (Axial Diameter - 25 nm) (Wavelength 550 nm)** 5ml
red liq. 25ml

NEW→

Color and Form: red liq.

Axial Diameter (nm): 25 ($\pm 10\%$)

Peak Longitudinal Surface Plasmon Resonance Wavelength (nm): 550

Peak Axial Surface Plasmon Resonance Wavelength (nm): 530

Storage Conditions: store at $\sim 4^{\circ}\text{C}$ (do not freeze)

Shelf Life: 6 months

Concentration: 171 ug/ml ($\pm 10\%$)

Longitudinal Size (nm): 34 ($\pm 10\%$)

79-6005 **Gold Nanorods (Axial Diameter - 25 nm) (Wavelength 600 nm)** 5ml
blue liq. 25ml

NEW→

Color and Form: blue liq.

Axial Diameter (nm): 25 ($\pm 10\%$)

Peak Longitudinal Surface Plasmon Resonance Wavelength (nm): 600

Peak Axial Surface Plasmon Resonance Wavelength (nm): 530

Storage Conditions: store at $\sim 4^{\circ}\text{C}$ (do not freeze)

Shelf Life: 6 months

Concentration: 235 ug/ml ($\pm 10\%$)

Longitudinal Size (nm): 47 ($\pm 10\%$)

79-6010 **Gold Nanorods (Axial Diameter - 25 nm) Wavelength 650 nm)** 5ml
blue liq. 25ml

NEW→

Color and Form: blue liq.

Axial Diameter (nm): 25 ($\pm 10\%$)

Peak Longitudinal Surface Plasmon Resonance Wavelength (nm): 650

Peak Axial Surface Plasmon Resonance Wavelength (nm): 530

Storage Conditions: store at $\sim 4^{\circ}\text{C}$ (do not freeze)

Shelf Life: 6 months

Concentration: 150 ug/ml ($\pm 10\%$)

Longitudinal Size (nm): 60 ($\pm 10\%$)

79-6015 **Gold Nanorods (Axial Diameter - 25 nm) (Wavelength 700 nm)** 5ml
pale red liq. 25ml

NEW→

Color and Form: pale red liq.

Axial Diameter (nm): 25 ($\pm 10\%$)

Peak Longitudinal Surface Plasmon Resonance Wavelength (nm): 700

Peak Axial Surface Plasmon Resonance Wavelength (nm): 530

Storage Conditions: store at $\sim 4^{\circ}\text{C}$ (do not freeze)

Shelf Life: 6 months

Concentration: 91 ug/ml ($\pm 10\%$)

Longitudinal Size (nm): 73 ($\pm 10\%$)

GOLD NANOMATERIALS

96-1530 Gold Nanorods Kit (Axial Diameter - 25 nm, wavelength 550-700 nm) 1 kit

NEW→

Contains 25ml unit of each of the following:

79-6000	Gold Nanorods (Axial Diameter - 25 nm) (Wavelength 550 nm)
79-6005	Gold Nanorods (Axial Diameter - 25 nm) (Wavelength 600 nm)
79-6010	Gold Nanorods (Axial Diameter - 25 nm) (Wavelength 650 nm)
79-6015	Gold Nanorods (Axial Diameter - 25 nm) (Wavelength 700 nm)

79-6020 Gold Nanorods (Axial Diameter - 10 nm) (Wavelength 700 nm)

5ml

NEW→

pale red-brown liq.

25ml

Color and Form:	pale red-brown liq.	Concentration:	30 ug/ml ($\pm 10\%$)
Axial Diameter (nm):	10 ($\pm 10\%$)	Longitudinal Size (nm):	29 ($\pm 10\%$)
Peak Longitudinal Surface Plasmon Resonance Wavelength (nm):	700		
Peak Axial Surface Plasmon Resonance Wavelength (nm):	512		
Storage Conditions:	store at $\sim 4^{\circ}\text{C}$ (do not freeze)		
Shelf Life:	6 months		

79-6025 Gold Nanorods (Axial Diameter - 10 nm) (Wavelength 750 nm)

5ml

NEW→

pale red liq.

25ml

Color and Form:	pale red liq.	Concentration:	34 ug/ml ($\pm 10\%$)
Axial Diameter (nm):	10 ($\pm 10\%$)	Longitudinal Size (nm):	35 ($\pm 10\%$)
Peak Longitudinal Surface Plasmon Resonance Wavelength (nm):	750		
Peak Axial Surface Plasmon Resonance Wavelength (nm):	512		
Storage Conditions:	store at $\sim 4^{\circ}\text{C}$ (do not freeze)		
Shelf Life:	6 months		

79-6030 Gold Nanorods (Axial Diameter - 10 nm) (Wavelength 780 nm)

5ml

NEW→

pale red solution

25ml

Color and Form:	pale red solution	Concentration:	35 ug/ml ($\pm 10\%$)
Axial Diameter (nm):	10 ($\pm 10\%$)	Longitudinal Size (nm):	38 ($\pm 10\%$)
Peak Longitudinal Surface Plasmon Resonance Wavelength (nm):	780		
Peak Axial Surface Plasmon Resonance Wavelength (nm):	512		
Storage Conditions:	store at $\sim 4^{\circ}\text{C}$ (do not freeze)		
Shelf Life:	6 months		

79-6035 Gold Nanorods (Axial Diameter - 10 nm) (Wavelength 808 nm)

5ml

NEW→

pale red liq.

25ml

Color and Form:	pale red liq.	Concentration:	36 ug/ml ($\pm 10\%$)
Axial Diameter (nm):	10 ($\pm 10\%$)	Longitudinal Size (nm):	41 ($\pm 10\%$)
Peak Longitudinal Surface Plasmon Resonance Wavelength (nm):	808		
Peak Axial Surface Plasmon Resonance Wavelength (nm):	512		
Storage Conditions:	store at $\sim 4^{\circ}\text{C}$ (do not freeze)		
Shelf Life:	6 months		

96-1535 Gold Nanorods Kit (Axial Diameter - 10 nm, wavelength 700-808 nm)

1 kit

NEW→

Contains 25ml unit of each of the following:

79-6020	Gold Nanorods (Axial Diameter - 10 nm) (Wavelength 700 nm)
79-6025	Gold Nanorods (Axial Diameter - 10 nm) (Wavelength 750 nm)
79-6030	Gold Nanorods (Axial Diameter - 10 nm) (Wavelength 780 nm)
79-6035	Gold Nanorods (Axial Diameter - 10 nm) (Wavelength 808 nm)

GOLD NANOMATERIALS

79-0144 NEW→	Gold Nanotriangles, nanohexagons, nanopolygons and nanorods [AuNP-Triangles, hexagons, polygons, rods (Glucose)] maroon-red liq.	5ml
Properties: Water soluble Color: Maroon-Red Ratio: Triangles: Hexagons: Polygons: Rod = 12:22:11:1 (see below) Shape: Mixture of triangles, hexagons, polygons, and rods UV-Vis (nm): 535-545 nm Ordering Specifications: Supplied as kit; For best results, use within 24 hours of generation. •Supplied as kit, contains sugars as stabilizer. •Suitable for in vitro use and sensor design applications. •Suitable for spin coating, self-assembly and monolayer formation. •Sensor design, nanoelectronics and MEMS applications.		
79-0142 NEW→	Gold Nanotriangles, nanohexagons, nanopolygons and nanorods [AuNP-Triangles, hexagons, polygons, rods (Maltose)] maroon-red liq.	5ml
Technical Note: 1. See 79-0144 (page 34).		
79-0138 NEW→	Gold Nanotriangles, nanohexagons, nanopolygons and nanorods [AuNP-Triangles, hexagons, polygons, rods (Sucrose)] maroon-red liq.	5ml
Technical Note: 1. See 79-0144 (page 34).		
79-0080	Gold/tetra-n-octylammonium chloride colloid 2.6 nm ± 1.1 nm; brown-orange solid (store cold) Note: Made to order. Long term shelf life not established.	250mg 1g
Technical Note: 1. Soluble in toluene. Precursor for CO-oxidation catalysts.		
79-0102 NEW→	Water Soluble Gold Nanoparticles [AuNP: 4-12 nm (gum Arabic)] maroon-red liq.	25ml 100ml
Properties: Water soluble, stable at pH 7.0 Size: 4-12 nm, 6-30 or 16-20 nm Color: Maroon-Red Shape: Sphere Stability: Stable for 90 days in aqueous media. UV-Vis (nm): 530 nm to 540 nm •Supplied in aqueous solutions . Contains gum arabic stabilizer. •Stable towards cysteine, Bovine serum albumin or Human serum albumin. •No agglomeration in 25 % NaCl solution. •Suitable for in vitro use and sensor design applications.		
References: 1. <i>Small</i>, 2007, 2, 333. 2. <i>Appl. Phys. Lett.</i>, 2006, 88, 153114. 3. <i>J. Am. Chem. Soc.</i>, 2006, 128, 11342.		
79-0104 NEW→	Water Soluble Gold Nanoparticles [AuNP: 6-30 nm (gum Arabic)] maroon-red liq.	25ml
Technical Note: 1. See 79-0102 (page 34).		

GOLD NANOMATERIALS

79-0106 NEW→	Water Soluble Gold Nanoparticles [AuNP: 16-20 nm (gum Arabic)] maroon-red liq.	25ml 100ml
Technical Note: 1. See 79-0102 (page 34).		
79-0110 NEW→	Water Soluble Gold Nanoparticles [AuNP: 3nm (Citrate)] wine-red liq.	25ml 100ml
Properties: Water soluble Color: Wine-Red Shape: Sphere Stability: Stable for 90 days in aqueous media. •Supplied in aqueous solutions. Contains citrate stabilizer. •Suitable for spin coating, self-assembly and monolayer formation.		
79-0112 NEW→	Water Soluble Gold Nanoparticles [AuNP: 5nm (Citrate)] wine-red liq.	25ml 100ml
Technical Note: 1. See 79-0110 (page 35).		
79-0114 NEW→	Water Soluble Gold Nanoparticles [AuNP: 10 nm (Citrate)] wine-red liq.	25ml 100ml
Technical Note: 1. See 79-0110 (page 35).		
79-0116 NEW→	Water soluble Gold Nanoparticles [AuNP: 15 nm (Citrate)] wine-red liq.	25ml 100ml
Technical Note: 1. See 79-0110 (page 35).		
79-0126 NEW→	Water Soluble Gold Nanoparticles [AuNP: 11-20 nm (Gelatin)] wine-red liq.	25ml 100ml
Properties: Water soluble Color: Wine-Red Shape: Sphere Stability: Stable for 90 days in aqueous media. •Suitable for spin coating, self-assembly and monolayer formation. •Suitable for in vitro use and sensor design applications.		
79-0108 NEW→	Water Soluble Gold Nanoparticles [AuNP: 30-40 nm (Starch)] maroon-red liq.	25ml 100ml
Properties: Water soluble, stable at pH 7.0 Color: Maroon-Red Shape: Sphere Stability: Stable for 30 days in aqueous media. •Supplied in aqueous solutions. Contains starch stabilizer. •Suitable for spin coating, self-assembly and monolayer formation.		
References: 1. <i>Appl. Phys. Lett.</i> , 2006 , 88, 153114. 2. <i>J. Am. Chem. Soc.</i> , 2006 , 128, 11342.		

New Products Introduced Since Catalog 22

CARBON (Elemental forms)

06-0172	Carbon, Stacked Graphene platelet nanochips	1g
NEW→	(SGNF heat treated) black powdr.	5g
	Note: Sold in collaboration with Catalyx Nanotech for research purposes only. See www.strem.com for more technical details.	25g
	Mean width: 40-50 nm	Range of length: 0.1-10 microns
	Density: 0.3 g/cm ³	Surface Area: 120 m ²
	Electrical Resistivity: 55 μWcm	

06-0170	Carbon, Stacked Graphene platelet nanofibers	1g
NEW→	(acid washed) SGNF black powdr.	5g
	Note: Sold in collaboration with Catalyx Nanotech for research purposes only. See www.strem.com for more technical details.	25g
	Mean width: 40-50 nm	Range of length: 0.1-10 microns
	Density: 0.3 g/cm ³	Surface Area: 120 m ²
	Electrical Resistivity: 120 μWcm	

CARBON (Compounds)

06-0114	2-Bromo-1,1'-binaphthyl, 98% [207611-58-3]	500mg
NEW→	C ₂₀ H ₁₃ Br; FW: 333.22; white powdr.	2g
06-0477	2,2'-Dibromobiphenyl, 98+% [13029-09-9]	1g
NEW→	C ₁₂ H ₈ Br ₂ ; FW: 312.00; white powdr.	5g

CHROMIUM (Compounds)

24-0280	Chromium(III) chloride tetrahydrofuran adduct, 98% [10170-68-0]	5g
NEW→	CrCl ₃ (C ₄ H ₈ O) ₃ ; FW: 374.67; purple powdr.	25g
HAZ	<i>moisture sensitive</i>	

COBALT (Compounds)

27-0478	1,2-Bis(diphenylphosphino)ethanedichlorocobalt(II), min. 97% [18498-01-6]	1g
NEW→	CoCl ₂ (C ₂₆ H ₂₄ P ₂); FW: 528.26; green powdr. <i>air sensitive</i>	5g

Technical Note: Catalyst for a variety of transformations- visit www.strem.com.

27-1050	Chlorotris(triphenylphosphine)cobalt(I), min. 98% [23670-75-9]	1g
NEW→	CoCl(P(C ₆ H ₅) ₃) ₃ ; FW: 881.24; brown powdr. <i>air sensitive, (store cold)</i>	5g

27-0528	(1S,2S)-(+)-1,2-Cyclohexanediamino-N,N'-bis(3,5-di-t-butylsalicylidene)cobalt(III) p-toluenesulfonate monohydrate [672306-06-8]	1g
NEW→	C ₄₃ H ₅₉ CoN ₂ O ₅ S•H ₂ O; FW: 774.94; green solid	5g

Technical Notes:

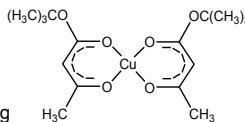
1. Useful catalyst for the enantiospecific addition of carbon dioxide to propylene oxide.
2. Catalyst used for the direct synthesis of optically active propylene carbonate from racemic epoxides.

References:

1. *Org. Let.*, **2006**, 8, 4401.
2. *J. Am. Chem. Soc.*, **2006**, 126, 3732.

COPPER (Compounds)

29-7110	Bis(t-butylacetoacetato)copper(II), 99% [23670-45-3]	1g
NEW→	C ₁₆ H ₂₆ CuO ₆ ; FW: 377.92; purple xtl.	5g
		25g



Technical Note:

1. A new, non-fluorinated, copper CVD precursor exhibiting a higher sublimation rate and lower decomposition rate than Cu(dpm)₂.

Reference:

1. *J. Mater. Res.*, **1998**, 13, 687.

New Products Introduced Since Catalog 22

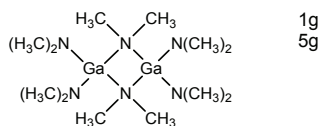
CYLINDERS & ADAPTERS

96-1070 Swagelok® Cylinder Assembly, 50ml with 1/4" VCR Male Ball Valve and Female Nut 1cyl
NEW→

96-1071 Swagelok® Cylinder Assembly, 50ml with 1/4" VCR Male Bellows-Sealed Valve (High Temp) and Female Nut 1cyl
NEW→

GALLIUM (Compounds)

31-2030 Bis(μ -dimethylamino)tetrakis(dimethyl-amino)digallium, 98% [57731-40-5]
NEW→ $C_{12}H_{36}Ga_2N_6$; FW: 403.90; white xtl.
 amp *moisture sensitive*
 HAZ



Technical Note:

- Useful precursor for the CVD and ALD of gallium oxide films, pyrolysis to GaN quantum dots, and the preparation of gallium nitride nanoparticles. See www.strem.com for additional information.

31-1300 Gallium(III) trifluoromethanesulfonate, 98% (Gallium triflate) 1g
NEW→ [74974-60-0] 5g
 HAZ $Ga(CF_3SO_3)_3$; FW: 516.93; white powdr.
hygroscopic

IRON (Compounds)

26-0160 1,1'-Bis(dichlorophosphino)ferrocene, 98% [142691-70-1] 500mg
NEW→ $C_{10}H_8Cl_4FeP_2$; FW: 387.77; yellow powdr. 2g
 HAZ *moisture sensitive*

26-0460 Bromoferrocene, 97% [1273-73-0] 500mg
NEW→ $C_{10}H_8BrFe$; FW: 264.93; orange solid 2g

26-0952 1,1'-Dibromoferrocene, 97% [1293-65-8] 500mg
NEW→ $C_{10}H_8Br_2Fe$; FW: 343.82; yellow-orange solid 2g

26-2830 Iron(II) trifluoromethanesulfonate, 98% (Iron triflate) [59163-91-6] 25g
NEW→ $Fe(CF_3SO_3)_2$; FW: 353.99; off-white to brown powdr. 100g
 HAZ *hygroscopic*

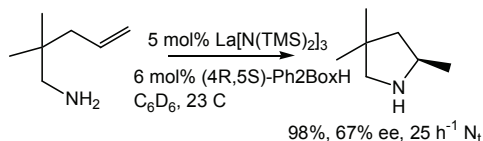
LANTHANUM (Compounds)

57-2550 Lanthanum(III) i-propoxide, 99% (99.9%-La) (REO) [19446-52-7] 1g
NEW→ $La(OC_3H_7)_3$; FW: 316.17; white to off-white powdr. 5g
moisture sensitive

57-0510 Tris(N,N-bis(trimethylsilyl)amide)lanthanum(III), min. 98% (99.9%-La) (REO) [175923-07-6] 1g
NEW→ $\{[(CH_3)_3Si]_2N\}_3La$; FW: 620.06; white powdr. 5g
 amp *air sensitive, moisture sensitive, (store cold)*

Technical Notes:

- Catalyst precursor for enantioselective intramolecular hydroamination of aminoalkenes and aminodienes.
- Catalyzes a mild and highly selective addition of terminal alkynes to nitriles to form conjugated ynones.
- Catalytic amidation of aldehydes with amines.



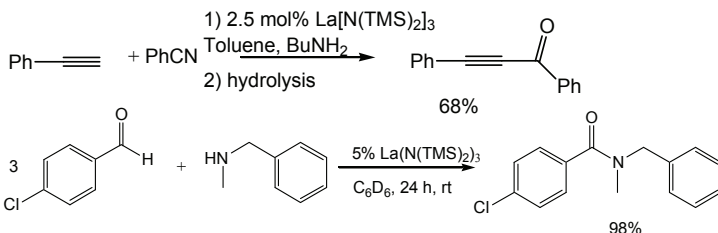
Tech. Note (1)
Ref. (1,2)

New Products Introduced Since Catalog 22

LANTHANUM (Compounds)

57-0510 Tris(N,N-bis(trimethylsilyl)amide)lanthanum(III), min. 98% (99.9%-La) (REO) [175923-07-6]

NEW→
amp
(cont.)



Tech. Note (2)
Ref. (3)

Tech. Note (3)
Ref. (4)

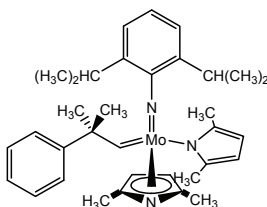
References:

1. *J. Am. Chem. Soc.*, **2003**, 125, 14768.
2. *Organometallics*, **2004**, 23, 2601.
3. *Organometallics*, **2008**, 27, 301.
4. *Org. Lett.*, **2008**, 10, 317.

MOLYBDENUM (Compounds)

42-1215 2,6-Di-*i*-propylphenylimido-neophylidene[di(2,5-dimethylpyrrolyl)]molybdenum(VI)
 $C_{34}H_{45}MoN_3$; FW: 591.68;
yellow to orange powdr.
air sensitive, (store cold)

NEW→
amp



100mg
500mg

NANOMATERIALS (Elemental forms)

06-0172 Carbon, Stacked Graphene platelet nanochips
(SGNF heat treated) *SEE CARBON SECTION (page 36)*

NEW→

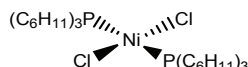
06-0170 Carbon, Stacked Graphene platelet nanofibers
(acid washed) SGNF *SEE CARBON SECTION (page 36)*

NEW→

NICKEL (Compounds)

28-0091 Bis(tricyclohexylphosphine)nickel(II) chloride, 99% [19999-87-2]
 $[(C_6H_{11})_3P]_2NiCl_2$; FW: 690.46;
dark red-purple xtls.

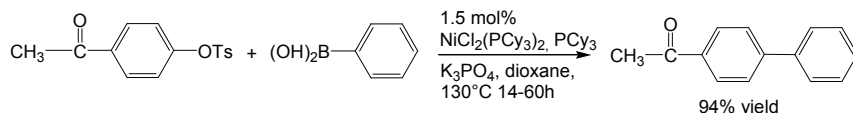
NEW→



1g
5g

Technical Note:

1. Efficient pre-catalyst for the Suzuki-Miyaura coupling of aryl tosylates and aryl pivalates with arylboronic acids.



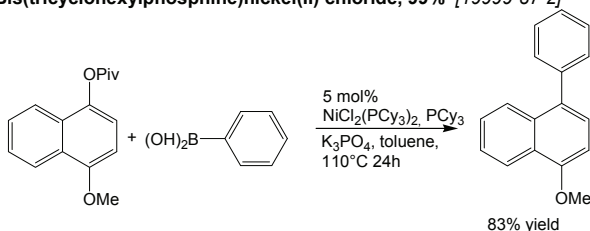
Tech. Note (1)
Ref. (1)

New Products Introduced Since Catalog 22

NICKEL (Compounds)

28-0091 Bis(tricyclohexylphosphine)nickel(II) chloride, 99% [19999-87-2]

NEW→
(cont.)



Tech. Note (1)
Ref. (2)

References:

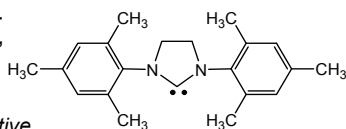
1. *Org. Lett.*, **2001**, 3, 3049.
2. *J. Am. Chem. Soc.*, **2008**, 130, 14422.

NITROGEN (Compounds)

07-0605 1,3-Bis(2,4,6-trimethylphenyl)-

NEW→
HAZ

4,5-dihydroimidazol-2-ylidene,
min. 98% [173035-11-5]
C₂₁H₂₆N₂; FW: 306.45;
white to off-white powdr.
air sensitive, moisture sensitive

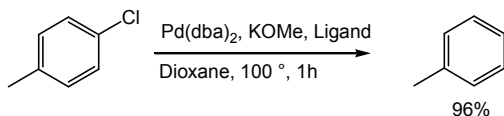


500mg
2g

Technical Notes:

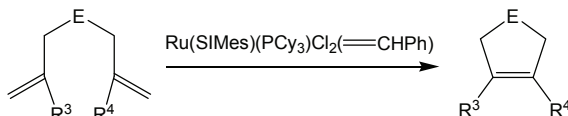
1. Nucleophilic carbene that serves as a bulky, electron-rich "phosphine mimic" for metal-catalyzed reactions.

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



Ref. (1)

(b) Ruthenium- SIMes is part of the Grubbs II Ruthenium catalyst for ring-closing metathesis Ref. (2,3). The catalyst RuHCl(CO)SIMes(PPh₃) has been used for hydrogenation of unactivated internal olefins (Ref 4).



Ref. (2,3)

(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).

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.

07-0319 trans-1,2-Cyclohexanediaminetetraacetic acid monohydrate,

NEW→

99+% [13291-61-7]
(HOOCCH₂)₂NC₆H₁₀N(CH₂COOH)₂·H₂O; FW: 346.32 (364.36);
white xtl.

25g
100g

New Products Introduced Since Catalog 22

NITROGEN (Compounds)

07-0488

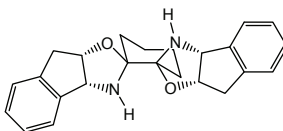
NEW→

(1''R,2''R,3aS,3''aS,8aR,8''aR)-
(+)-3,3''-3a,3''a, 8,8'',8a,8''a-Octa-
hydrodispiro[2H-indeno[1,2-d]
oxazole-2,1'-cyclohexane-
2',2''-[2H] indeno[1,2-d]oxazole}
WOLF BISOXAZOLIDINE

[947515-50-6]

C₂₄H₂₆N₂O₂; FW: 374.48; white powdr.; [α]_D +65.2° (c 1.0, CHCl₃)

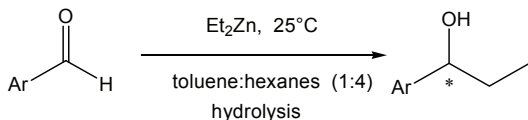
Note: Sold under license from Georgetown University for research purposes only. Patent pending.



250mg
1g

Technical Note:

1. Catalyst used in the asymmetric addition of diethylzinc to aldehydes – synthesis of chiral alcohols.
catalyst (2 mole %)



Reference:

1. *Org. Lett.*, **2007**, *9*, 2965.

OXYGEN (Compounds)

08-0180

NEW→

2,2'-Bis(trifluoromethanesulfonyloxy)-1,1'-biphenyl, 99%
(1,1'-Biphenol bistriflate) [17763-95-0]

C₁₄H₈F₆O₆S₂; FW: 450.33; white powdr.

250mg
1g

PALLADIUM (Elemental forms)

46-1710

NEW→

Palladium, 0.6% on activated carbon, 50% water-wet paste
(NanoSelect LF 100) [7440-05-3]
black powdr. (d50=25 μm)

Note: Sold in collaboration with BASF for research purposes only.

BASF Heterogeneous Catalyst Kit (see page 51) and BASF Palladium Catalyst Kit component (see page 52).

5g
25g

Technical Note:

1. NanoSelect LF 100 is a lead-free, water-wet, catalyst containing metal crystallites sizes of around 7 nm, and a mean particle size of 25 microns. The metal crystallites are supported on a carbon powder. The presence of nanometer-sized metal particles greatly increases the metal surface area available per gram of catalyst, and boosts catalytic activity. The catalyst is recommended for use in hydrogenation reactions leading to the partial reduction of functional groups. It is specifically suited for the selective hydrogenation of alkynes to alkenes, with a high selectivity for cis- alkenes.

46-1711

NEW→

Palladium, 0.5% on titanium silicate, 50% water-wet paste
(NanoSelect LF 200) [7440-05-3]
black powdr. (d50=25 μm)

Note: Sold in collaboration with BASF for research purposes only.

5g
25g

Technical Note:

1. NanoSelect LF 200 is a lead-free, water-wet, catalyst containing metal crystallites sizes of around 7 nm, and a mean particle size of 25 microns. The metal crystallites are supported on titanium silicate powder. The presence of nanometer-sized metal particles greatly increases the metal surface area available per gram of catalyst, and boosts catalytic activity. The catalyst is recommended for use in hydrogenation reactions leading to the partial reduction of functional groups. It is specifically suited for the selective hydrogenation of alkynes to alkenes, with a high selectivity for cis-alkenes.

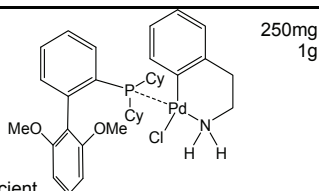
New Products Introduced Since Catalog 22

PALLADIUM (Compounds)

96-6717 **BASF Heterogeneous Catalyst Kit**
NEW→ (See page 51).

96-6719 **BASF Palladium Catalyst Kit**
NEW→ (See page 52).

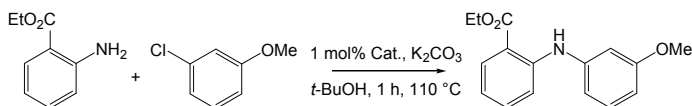
46-0269 **Chloro(2-dicyclohexylphosphino-2',6'-dimethoxy-1,1'-biphenyl)[2-(2-aminoethyl-phenyl)]palladium(II) dichloromethane adduct, min. 98% [1028206-58-7]**
 $C_{34}H_{45}ClNO_2PPd$; FW: 672.57; white powdr.
 Note: Patents: US 6,395,916, US 6,307,087



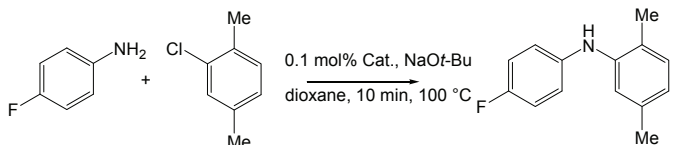
250mg
1g

Technical Notes:

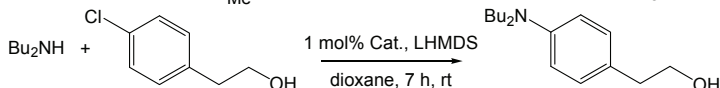
1. Catalyst for cross-coupling reactions of electron-deficient anilines with aryl chlorides.
2. Catalyst for rapid C-N bond-forming process at low catalyst loading.
3. Catalyst for C-N cross-coupling reactions, at or below room temperature.



Tech. Note (1)
Ref. (1)



Tech. Note (2)
Ref. (1)



Tech. Note (3)
Ref. (1)

Reference:

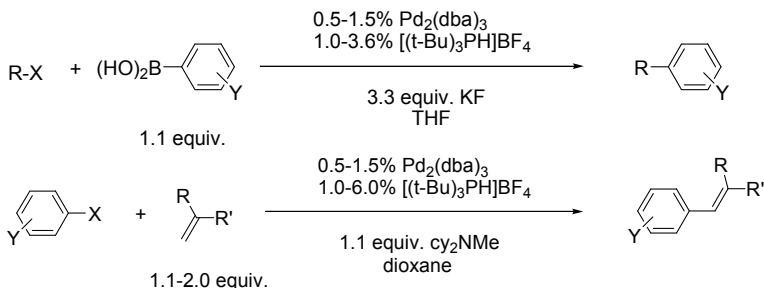
1. *J. Am. Chem. Soc.*, **2008**, *130*, 6686.

46-3015 **Tris(dibenzylideneacetone)dipalladium(0)/tri-*t*-butylphosphonium tetrafluoroborate admixture (molar Pd/P = 1:1.2)**
 $C_{51}H_{42}O_3Pd_2[(C_4H_9)_3PH]^+BF_4^-$; purple powdr.
air sensitive, moisture sensitive

1g
5g

Technical Note:

1. Stable, precatalyst mixture for the Suzuki, Heck, Stille, and Sonogashira, reactions of aryl/vinyl halides, under mild conditions. Active catalyst can be generated in situ by adding a base.

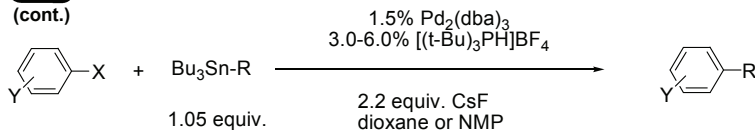


New Products Introduced Since Catalog 22

PALLADIUM (Compounds)

46-3015 Tris(dibenzylideneacetone)dipalladium(0)/tri-*t*-butylphosphonium tetrafluoroborate admixture (molar Pd/P = 1:1.2)

NEW→
(cont.)



Reference:

1. *Org. Lett.* **2001**, 3, 4295.

46-3020 Tris(dibenzylideneacetone)dipalladium(0)/tri-*t*-butylphosphonium tetrafluoroborate admixture (molar Pd/P = 1:2)

NEW→

1g
5g

$C_{51}H_{42}O_3Pd_2[(C_4H_9)_3PH]^+BF_4^-$; purple powdr.
air sensitive, moisture sensitive

Technical Note:

1. See 46-3015 (page 41).

PHOSPHORUS (Compounds)

96-7050 PINAP Ligand Kit

1 kit

NEW→

(See page 53).

Contains 250mg unit of each of the following:

- | | |
|---------|--|
| 15-1782 | (R)-(+)-4-[2-(Diphenylphosphino)-1-naphthalenyl]-N-[(R)-1-phenylethoxy]phthalazine, min. 97% (R,R)-O-PINAP [828927-95-3] |
| 15-1783 | (S)-(-)-4-[2-(Diphenylphosphino)-1-naphthalenyl]-N-[(R)-1-phenylethoxy]phthalazine, min. 97% (R,S)-O-PINAP [828927-94-2] |
| 15-1784 | (R)-(+)-4-[2-(Diphenylphosphino)-1-naphthalenyl]-N-[(R)-1-phenylethyl]-1-phthalazinamine, min. 97% (R,R)-N-PINAP [828927-97-5] |
| 15-1786 | (S)-(-)-4-[2-(Diphenylphosphino)-1-naphthalenyl]-N-[(R)-1-phenylethyl]-1-phthalazinamine, min. 97% (R,S)-N-PINAP [828927-96-4] |
| 15-1787 | (R)-(+)-4-[2-(Diphenylphosphino)-1-naphthalenyl]-N-[(S)-1-phenylethyl]-1-phthalazinamine, min. 97% (S,R)-N-PINAP |

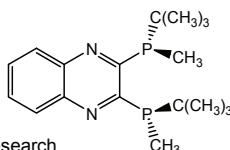
15-0126 (R,R)-(-)-2,3-Bis(*t*-butylmethylphosphino)quinoxaline

NEW→

(R,R)-QuinoxP* [866081-62-1]

$C_{18}H_{28}N_2P_2$; FW: 334.38; orange powdr.; $[\alpha]_D^{25}$ -54.3° (c 1.0, $CHCl_3$); m.p. 102-103°

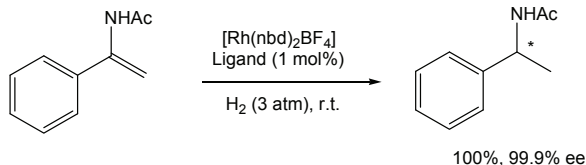
Note: Sold in collaboration with JCI for research purposes only. Patent pending.



100mg
500mg

Technical Notes:

1. Ligand for the rhodium-catalyzed, asymmetric hydrogenation of dehydroamino acid esters and α -enamides.
2. Ligand for the rhodium-catalyzed, asymmetric 1,4-addition of arylboronic acids to α,β -unsaturated carbonyl compounds.
3. Ligand for the rhodium-catalyzed, asymmetric alkylative ring opening reaction.
4. Ligand for the palladium catalyzed asymmetric allylic alkylation and amination of racemic substrates.
5. Ligand for the ruthenium catalyzed asymmetric hydrogenation of ketones.



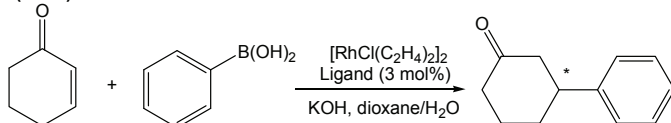
Tech Note (1)
Ref. (1)

New Products Introduced Since Catalog 22

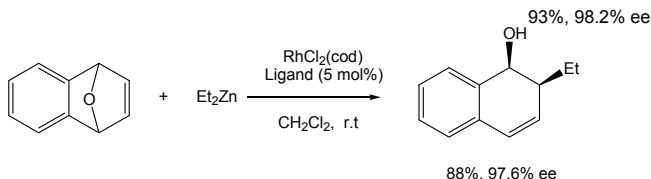
PHOSPHORUS (Compounds)

15-0126 (R,R)-(-)-2,3-Bis(t-butylmethyl-phosphino)quinoxaline (R,R)-QuinoxP* [866081-62-1]

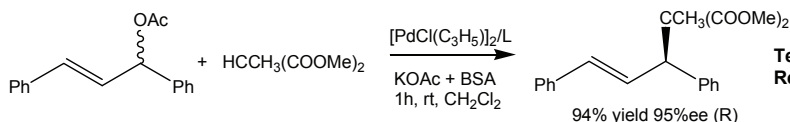
NEW→
(cont.)



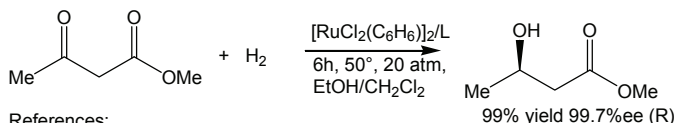
Tech Note (2)
Ref. (1)



Tech Note (3)
Ref. (1)



Tech Note (4)
Ref. (2)



Tech Note (5)
Ref. (2)

References:

1. J. Am. Chem. Soc., **2005**, 127, 11934.
2. J. Org. Chem., **2007**, 72, 7413.

15-0127 (S,S)-(+)-2,3-Bis(t-butylmethylphosphino)quinoxaline, min. 98%

NEW→

(S,S)-QuinoxP*

C₁₈H₂₈N₂P₂; FW: 334.38; orange powdr.; [α]_D +54.3° (c 1.0, CHCl₃);

m.p. 102-103°

Note: Sold in collaboration with JCI for research purposes only.

Patent pending.

100mg
500mg

Technical Note:

1. See 15-0126 (page 42).

15-0069 1,2-Bis(dichlorophosphino)benzene, 98% [82495-67-8]

NEW→

amp

C₆H₄Cl₂P₂; FW: 279.85; colorless to pale yellow liq.

moisture sensitive

500mg
2g

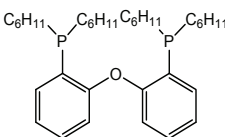
15-0048 Bis(2-dicyclohexylphosphinophenyl)

NEW→

ether, 98% [434336-16-0]

C₃₆H₅₂OP₂; FW: 562.75;

white powdr.



500mg
2g

15-9593 1,3-Bis(dicyclohexylphosphonium)propane bis(tetrafluoroborate),

NEW→

min. 97% [1002345-50-7]

[(C₆H₁₁)₂PCH₂CH₂CH₂P(C₆H₁₁)₂]⁺·2HBF₄⁻; FW: 612.26; white powdr.

hygroscopic

1g
5g

New Products Introduced Since Catalog 22

PHOSPHORUS (Compounds)

15-9593 **1,3-Bis(dicyclohexylphosphonium)propane bis(tetrafluoroborate), min. 97%**

NEW→

(cont.)

[1002345-50-7]

Technical Notes:

1. Ligand for palladium-catalyzed carbonylation of aryl tosylates and mesylates.
2. Ligand for palladium-catalyzed aminocarbonylation of aryl chlorides at atmospheric pressure.

References:

1. *J. Am. Chem. Soc.*, **2008**, *130*, 2754.
2. *Angew. Chem. Int. Ed.*, **2007**, *46*, 8460.

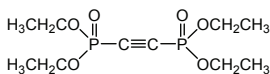
15-0119 **Bis(diethoxyphosphoryl)-**

NEW→

acetylene, 99% [4851-53-0]

$C_{10}H_{20}O_6P_2$; FW: 298.21; yellow liq.

moisture sensitive



500mg

2g

15-0111 **Bis(3,5-dimethyl-4-methoxyphenyl)chlorophosphine, min. 98%**

NEW→

HAZ

[136802-85-2]

$C_{18}H_{22}ClO_2P$; FW: 336.79; colorless, viscous liq.

moisture sensitive

500mg

2g

15-0443 **(R)-(+)-12,12'-Bis(diphenylphosphino)-**

NEW→

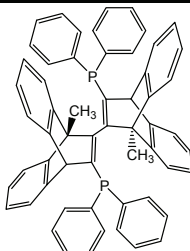
9,9'-dimethyl-10,10'-dihydro-11,11'-bi-

9,10-ethenoanthracene, min. 98%

(R)-Me-CATPHOS

$C_{68}H_{44}P_2$; FW: 802.92; white xtl.;

$[\alpha]_D^{+98.6^\circ}$ (c 1.0, CH_2Cl_2)



250mg

1g

Technical Note:

1. See 15-0442 (Visit www.strem.com).

15-0114 **Bis(3,5-di(trifluoromethyl)phenyl)chlorophosphine, min. 98%**

NEW→

HAZ

[142421-57-6]

$C_{16}H_6ClF_{12}P$; FW: 492.63; colorless liq.

moisture sensitive

500mg

2g

15-0115 **Bis(1-naphthyl)chlorophosphine, min. 97%** [36042-99-6]

NEW→

$C_{20}H_{14}ClP$; FW: 320.75; white to pale yellow xtl.

moisture sensitive

500mg

2g

15-0125 **2-Bromophenyldiphenylphosphine, 98%** [62336-24-7]

NEW→

$C_{18}H_{14}BrP$; FW: 341.18; white powdr.

1g

5g

15-0966 **t-Butylphosphine, min. 95% TBP** [2501-94-2]

NEW→

amp

HAZ

$(C_4H_9)PH_2$; FW: 90.10; colorless liq.; b.p. 54° ; d. 0.7; STENCH

pyrophoric

1g

5g

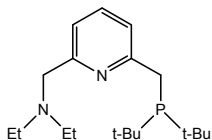
15-0073 **2-(Di-t-butylphosphinomethyl)-6-(diethyl-**

NEW→

aminomethyl)pyridine, 98% [863971-66-8]

$C_{19}H_{35}N_2P$; FW: 322.47; yellow liq.

air sensitive



100mg

500mg

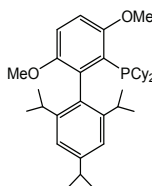
Technical Note:

1. See 44-0091 (Visit www.strem.com).

New Products Introduced Since Catalog 22

PHOSPHORUS (Compounds)

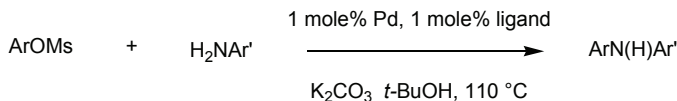
15-1152 **2-(Dicyclohexylphosphino)-3,6-dimethoxy-2'-4'-6'-tri-*i*-propyl-1,1'-biphenyl, min. 98% BrettPhos**
 $C_{35}H_{53}O_2P$; FW: 536.77; white xtl.; m.p. 191-193°
 Note: Buchwald Biaryl Phosphine Ligand Kit component. Patents: US 6,395,916, US 6,307,087



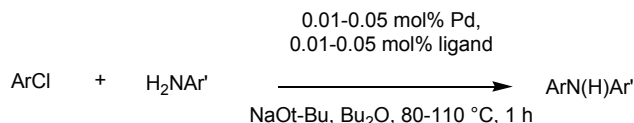
250mg
1g

Technical Notes:

1. Catalyst for cross-coupling reactions using aryl mesylates with electron-deficient anilines.
2. Catalyst for rapid C-N bond-forming process at low catalyst loading.



Tech. Note (1)
Ref. (1)

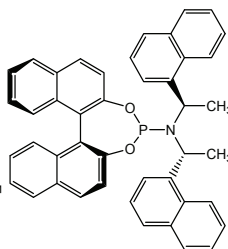


Tech. Note (2)
Ref. (1)

Reference

1. *J. Am. Chem. Soc.*, **2008**, *130*, 13552.

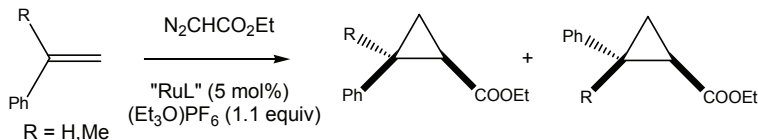
15-1257 **(S)-(+)-(3,5-Dioxo-4-phosphacyclohepta[2,1-a;3,4-a']dinaphthalen-4-yl) bis[(1R)-1-(1-naphthalenyl)ethyl] amine, min. 97% [342813-25-6]**
 $C_{44}H_{34}NO_2P$; FW: 639.72; white powdr.
moisture sensitive
 Note: Sold in collaboration with DSM for research purposes only.
 Patent WO 0204466. DSM's MonoPhos™ Ligand Kit component.



100mg
500mg

Technical Note:

1. Useful ligand for the ruthenium-catalyzed, enantioselective cyclopropanation of styrenes.

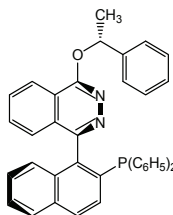


Tech. Note (1)
Ref. (1)

Reference:

1. *Organometallics*, **2005**, *24*, 5221.

15-1782 **(R)-(+)-4-[2-(Diphenylphosphino)-1-naphthalenyl]-N-[(R)-1-phenylethoxy] phthalazine, min. 97% (R,R)-O-PINAP [828927-95-3]**
 $C_{38}H_{29}N_2OP$; FW: 560.62; colorless xtl.; $[\alpha]_D^{25} +78.5^\circ$ (c 0.25, CHCl_3); m.p. 64-65°
air sensitive
 Note: PINAP Ligand Kit component (see page 53).



250mg
1g

Technical Note:

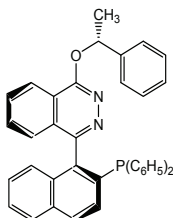
1. See 15-1783 (page 46).

PHOSPHORUS (Compounds)

15-1783

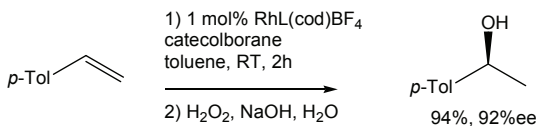
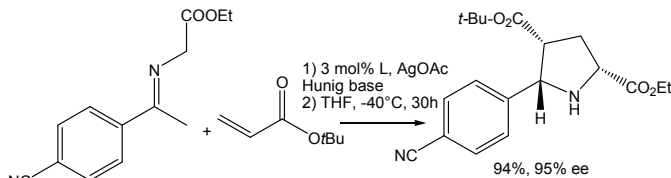
NEW→

(S)-(-)-4-[2-(Diphenylphosphino)-1-naphthalenyl]-N-[(R)-1-phenylethoxy]phthalazine, min. 97% (R,S)-O-PINAP [828927-94-2]
 $C_{38}H_{29}N_2OP$; FW: 560.62; colorless xtl.; $[\alpha]_D^{25}$ -160.4° (c 0.53, $CHCl_3$); m.p. 178-181°
air sensitive
 Note: PINAP Ligand Kit component (see page 53).

250mg
1g

Technical Notes:

1. The PINAP family of P,N ligands is a synthetically more accessible but a similarly performing analog of the QUINAP (15-1777, 15-1778) ligand in enantioselective hydroboration, alkyne addition, and azomethine cycloaddition reactions. (Ref. 1)
2. With rhodium, enantioselective hydroboration of alkenes as a route to chiral alcohols.
3. With silver, catalytic, enantioselective, azomethine cycloaddition with acrylates.

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

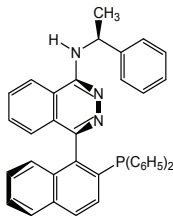
Reference:

1. *Angew. Chem. Int. Ed.*, **2004**, 43, 5971.

15-1787

NEW→

(R)-(+)-4-[2-(Diphenylphosphino)-1-naphthalenyl]-N-[(S)-1-phenylethyl]-1-phthalazinamine, min. 97% (S,R)-N-PINAP
 $C_{38}H_{30}N_3P$; FW: 559.64; colorless xtl.; m.p. >210°
air sensitive
 Note: PINAP Ligand Kit component (see page 53).

250mg
1g

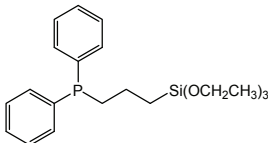
Technical Note:

1. See 15-1786 (Visit www.strem.com).

15-1823

NEW→

Diphenyl[3-(triethoxysilyl)propyl]phosphine, 98% [52090-23-0]
 $(C_6H_5)_2P(CH_2)_3Si(OCH_2CH_3)_3$; FW: 390.53; colorless, oily liq.
air sensitive, moisture sensitive

250mg
1g

Technical Note:

1. Useful ligand for the preparation of silica-immobilized metal catalysts.

New Products Introduced Since Catalog 22

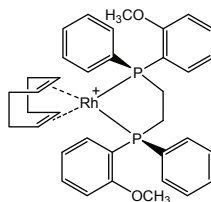
PLATINUM (Compounds)

96-6721 **BASF Platinum Catalyst Kit**

NEW→ (See page 52).

RHODIUM (Compounds)

45-0226 **(S,S)-(+)-1,2-Bis[(o-methoxyphenyl)(phenyl)phosphino]ethane (1,5-cyclooctadiene)rhodium(I) tetrafluoroborate, min. 95% [71423-54-6]**
 $[\text{Rh}(\text{C}_8\text{H}_{12})(\text{C}_{28}\text{H}_{28}\text{O}_2\text{P}_2)]^+\text{BF}_4^-$; FW: 756.38; orange powdr.
air sensitive



100mg
500mg

Technical Note:

- See 45-0225 (Visit www.strem.com).

45-0667 **(R)-(-)-t-Butylmethyl(di-t-butylphosphinomethyl)phosphino (1,5-cyclooctadiene)rhodium(I) tetrafluoroborate, min. 97% (R)-TCFP-Rh [705945-70-6]**
 $\text{Rh}(\text{C}_8\text{H}_{12})(\text{C}_{14}\text{H}_{32}\text{P}_2)^+\text{BF}_4^-$; FW: 560.24; yellow to orange powdr.
air sensitive

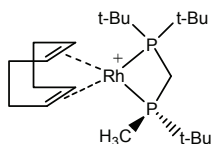
Note: Sold in collaboration with JM for research purposes only.
 Patent WO 2005087370.

100mg
500mg

Technical Note:

- See 45-0668 (page 47).

45-0668 **(S)-(+)-t-Butylmethyl(di-t-butylphosphinomethyl)phosphino(1,5-cyclooctadiene)rhodium(I) tetrafluoroborate, min. 97% (S)-TCFP-Rh [705945-68-2]**
 $\text{Rh}(\text{C}_8\text{H}_{12})(\text{C}_{14}\text{H}_{32}\text{P}_2)^+\text{BF}_4^-$; FW: 560.24;
 yellow to orange powdr.
air sensitive

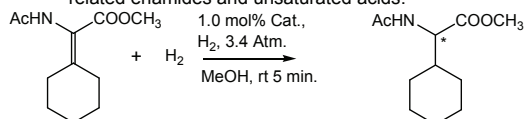


100mg
500mg

Note: Sold in collaboration with JM for research purposes only. Patent WO 2005087370.

Technical Note:

- Catalyst for highly enantioselective, rapid, hydrogenation of α and β -acetamido dehydroaminoacids and related enamides and unsaturated acids.



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

References:

100%; 99% ee

- J. Am. Chem. Soc.*, **2004**, 126, 5966.
- Org. Lett.*, **2004**, 6, 3645.
- J. Am. Chem. Soc.*, **2008**, 130, 2560.

RUTHENIUM (Compounds)

44-0030 **Bis(2,4-dimethylpentadienyl)ruthenium(II), 99% [85908-78-7]**
 $(\text{C}_7\text{H}_{11})_2\text{Ru}$; FW: 291.39; yellow solid; m.p. 85°;
 v.p. 0.17mm (100°) 2.2mm (150°)



250mg
1g

Technical Note:

- Volatile ruthenium complex, useful for the MOCVD of ruthenium and ruthenium oxide.

References:

- Electrochemical and Solid-State Letters*, **2007**, 10(6).

New Products Introduced Since Catalog 22

RUTHENIUM (Compounds)

44-0030 Bis(2,4-dimethylpentadienyl)ruthenium(II), 99% [85908-78-7]

NEW→

(cont.)

References (cont.):

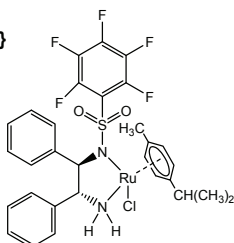
2. *ECS Transactions* **2006**, 1(5, Physics and Technology of High-k Gate Dielectrics III), 139-144.
3. *Journal of Crystal Growth*, **1998**, 195(1-4), 69-73.
4. *Materials Research Society Symposium Proceedings*, **1998**, 495(Chemical Aspects of Electronic Ceramics Processing), 51-55 and 75-80.

44-0156 Chloro{[(1R,2R)-(-)-2-amino-1,2-diphenylethyl](4-pentafluorophenylsulfonyl)amido}(p-cymene)ruthenium(II), min. 90% [1026995-71-0]

$C_{30}H_{28}ClF_5N_2O_2RuS$; FW: 712.14; orange to brown powdr.

air sensitive

Note: Manufactured under license of Takasago patent US7129367B2.



250mg
1g

Technical Note:

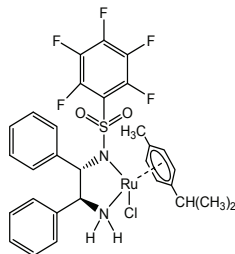
1. See 44-0155 (page 48).

44-0157 Chloro{[(1S,2S)-(+)-2-amino-1,2-diphenylethyl](4-pentafluorophenylsulfonyl)amido}(p-cymene)ruthenium(II), min. 90% [1026995-72-1]

$C_{30}H_{28}ClF_5N_2O_2RuS$; FW: 712.14; orange to brown powdr.

air sensitive

Note: Manufactured under license of Takasago patent US7129367B2.



250mg
1g

Technical Note:

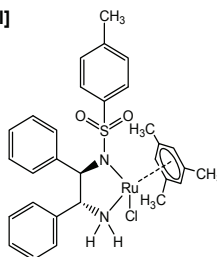
1. See 44-0155 (page 48).

44-0154 Chloro{[(1R,2R)-(-)-2-amino-1,2-diphenylethyl](4-toluenesulfonyl)amido}(mesitylene)ruthenium(II), min. 97% [174813-82-2]

$C_{30}H_{33}ClN_2O_2RuS$; FW: 622.18; orange powdr.

air sensitive

Note: Manufactured under license of Takasago patent US7129367B2.



250mg
1g

Technical Note:

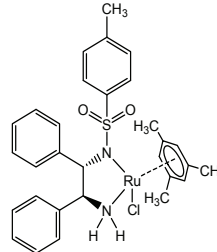
1. See 44-0155 (page 48).

44-0155 Chloro{[(1S,2S)-(+)-2-amino-1,2-diphenylethyl](4-toluenesulfonyl)amido}(mesitylene)ruthenium(II), min. 97% [174813-81-1]

$C_{30}H_{33}ClN_2O_2RuS$; FW: 622.18; orange powdr.

air sensitive

Note: Manufactured under license of Takasago patent US7129367B2.



250mg
1g

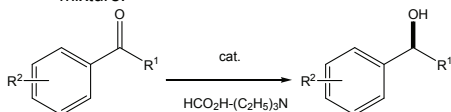
New Products Introduced Since Catalog 22

RUTHENIUM (Compounds)

44-0155 Chloro[[**(1S,2S)**-(+)-2-amino-1,2-diphenylethyl](4-toluenesulfonylamido)(mesitylene) ruthenium(II), min. 97% [174813-81-1]
NEW→
 (cont.)

Technical Note:

1. Catalyst used in the asymmetric transfer hydrogenation of ketones using formic acid-triethylamine mixture.

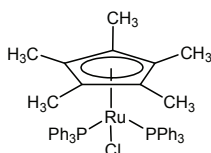


Tech. Note (1)
Ref. (1)

Reference:

1. *J. Am. Chem. Soc.*, **1996**, *118*, 2521.

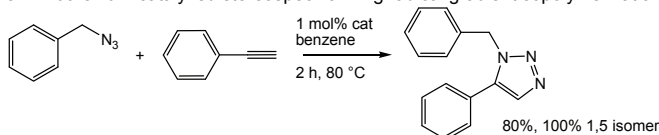
44-0117 Chloro(pentamethylcyclopentadienyl) bis(triphenylphosphine)ruthenium(II), 99%
NEW→
 [92361-49-4]
 RuCl(C₁₀H₁₅)[P(C₆H₅)₃]₂; FW: 796.32;
 orange powd.
 (store cold)



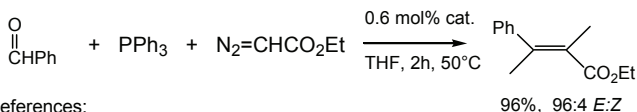
250mg
 1g

Technical Notes:

1. Effective catalyst for the regioselective cycloaddition of organic azides and terminal alkynes, producing 1,5-substituted triazoles. This "click" reaction complements the related copper catalyzed cycloaddition which favors the 1,4 substituted product.
2. One step catalytic alternative to the classic Wittig reaction.
3. Ruthenium catalyzed stereospecific living radical gradient copolymerization of acrylate monomer pairs.



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

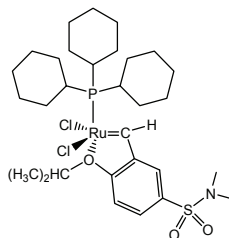


Tech. Note (2)
Ref. (3)

References:

1. *J. Am. Chem. Soc.*, **2005**, *127*, 15998.
2. *J. Am. Chem. Soc.*, **2008**, *130*, 8923.
3. *Organometallics*, **2007**, *26*, 302.

44-0078 {[2-(i-propoxy)-5-(N,N-dimethylamino-sulfonyl) phenyl]methylene} (tricyclohexylphosphine) ruthenium(II) dichloride
NEW→
Zhan Catalyst -1C [918871-44-0]
 C₃₀H₅₀Cl₂NO₃PRuS; 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

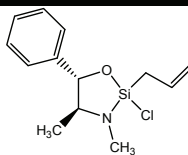
Technical Note:

1. See 44-0082 (Visit www.strem.com).

New Products Introduced Since Catalog 22

SILICON (Compounds)

14-1815 (4*S*,5*S*)-2-Allyl-2-chloro-3,4-dimethyl-
NEW→ 5-phenyl-1-oxa-3-aza-2-silacyclopentane,
 min. 98% (~2:1 mixture of diastereomers)
 [447440-43-9]
 $C_{13}H_{18}ClNOSi$; FW: 267.83; colorless oil
moisture sensitive, (store cold)
 Note: Patent WO 03/074534, WO 06/062901.



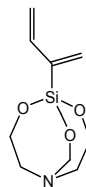
1g
5g

Technical Note:

- Useful reagent for enantioselective arylation and allylation reactions. See www.strem.com for specific reactions and references.

15-1823 Diphenyl[3-(triethoxysilyl)propyl]phosphine, 98%
NEW→ SEE PHOSPHORUS SECTION (page 46)

14-1960 2,2',2''-Nitrilotris(ethanolato)(buta-1,3-dien-2-yl)
NEW→ silane, min. 98% [1026785-83-0]
 $C_{10}H_{17}NO_3Si$; FW: 227.33; light yellow powdr.
moisture sensitive
 Note: Sold under license from Wake Forest University
 for research purposes only.
 PCT US2007/022872.



250mg
1g

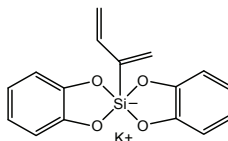
Technical Note:

- Reagent used in Diels-Alder cross-coupling reactions.

Reference:

- Org. Lett.*, **2007**, 9, 1623.

14-1965 Potassium bis(1,2-benzenediolato)
NEW→ (1,3-butadien-2-yl)silicate, min. 98%
 [1021940-25-9]
 $K^+[C_{16}H_{13}O_4Si]^-$; FW: 336.46; white xtl.
moisture sensitive
 Note: Sold under license from
 Wake Forest University for research
 purposes only. PCT US2007/022872.



250mg
1g

Technical Note:

- Reagent used in Diels-Alder cross-coupling reactions.

Reference:

- Org. Lett.*, **2007**, 9, 1623.

SILVER (Compounds)

47-3010 Triethoxyphosphine(trifluoroacetylacetonate)silver(I), min. 98%
NEW→ [783334-85-0]
 $Ag(CF_3COCHCOCH_3)P(OCH_2CH_3)_3$; FW: 427.10;
 yellow solid

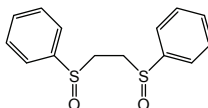
1g
5g

47-3025 Triethylphosphine(6,6,7,7,8,8,8-heptafluoro-2,2-dimethyl-
NEW→ 3,5-octanedionate)silver(I), min. 98% [165461-74-5]
 $Ag(C_8F_7COCHCOC_4H_9)P(CH_2CH_3)_3$; FW: 521.20; yellow solid

1g
5g

SULFUR (Compounds)

16-0350 1,2-Bis(phenylsulfinyl)ethane, 98%
NEW→ [6099-21-4]
 $C_{14}H_{14}O_2S_2$; FW: 278.39;
 white to off-white powdr.
(store cold)



250mg
1g

New Products Introduced Since Catalog 22

SULFUR (Compounds)

16-0610

NEW→

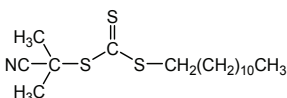
S-(2-Cyanoprop-2-yl)-S-dodecyl-trithiocarbonate, min. 97%

[870196-83-1]

C₁₇H₃₁NS₃; FW: 345.63; orange liq.

light sensitive; (store cold)

Note: Sold for research purposes only under license from CSIRO.



500mg

2g

Technical Note:

1. Sulfur-based agent providing a high degree of control for, Reversible Addition Fragmentation Chain Transfer (RAFT), polymerizations.

TERBIUM (Compounds)

65-6000

NEW→

Terbium(III) trifluoromethanesulfonate, min. 98%

(Terbium triflate) [148980-31-8]

Tb(CF₃SO₃)₃; FW: 606.14; white pwdr.

hygroscopic

1g

5g

TIN (Compounds)

50-1800

NEW→

Tetracyclohexyltin, 99% [1449-55-4]

Sn(C₆H₁₁)₄; FW: 451.32; white solid

1g

5g

BASF HETEROGENEOUS CATALYST KIT

96-6717

NEW→

BASF Heterogeneous Catalyst Kit

Components available for individual sale.

Contains the following:

46-1707	Palladium, 20% on activated carbon (Pearlman's catalyst), unreduced, 50% water wet paste (Escat™ 1951) [7440-05-3]	5g	Visit www.strem.com
46-1710	Palladium, 0.6% on activated carbon, 50% water-wet paste (NanoSelect LF 100) [7440-05-3]	5g	See page 40
46-1901	Palladium, 5% on activated peat carbon, reduced, 50% water wet paste (Escat™ 1621) [7440-05-3]	10g	Visit www.strem.com
46-1902	Palladium, 5% on activated wood carbon, reduced, dry (Escat™ 1431) [7440-05-3]	10g	Visit www.strem.com
46-1903	Palladium, 5% on activated wood carbon, reduced, 50% water wet paste (Escat™ 1421) [7440-05-3]	10g	Visit www.strem.com
46-1904	Palladium, 5% on activated wood carbon, unreduced, 50% water wet paste (Escat™ 1471) [7440-05-3]	10g	Visit www.strem.com
46-1905	Palladium, 10% on activated wood carbon, reduced, 50% water wet (Escat™ 1931) [7440-05-3]	10g	Visit www.strem.com
46-1951	Palladium, 5% on alumina powder, reduced, dry (Escat™ 1241) [7440-05-3]	5g	Visit www.strem.com
78-1611	Platinum, 5% on activated wood carbon, reduced, dry (Escat™ 2431) [7440-06-4]	5g	Visit www.strem.com
78-1612	Platinum, 5% on activated wood carbon, reduced, 50% water wet paste (Escat™ 2421) [7440-06-4]	5g	Visit www.strem.com
78-1613	Platinum, 5% on activated carbon, unreduced, 50% water wet paste (Escat™ 2441) [7440-06-4]	5g	Visit www.strem.com
45-1875	Rhodium, 5% on activated wood carbon, reduced, 50% water wet paste (Escat™ 3401) [7440-16-6]	1g	Visit www.strem.com
44-4065	Ruthenium, 5% on activated carbon, reduced, 50% water wet paste (Escat™ 4401) [7440-18-8]	5g	Visit www.strem.com

New Products Introduced Since Catalog 22

BASF PALLADIUM CATALYST KIT

96-6719

BASF Palladium Catalyst Kit

NEW→

Components available for individual sale.

Contains the following:

46-1707	Palladium, 20% on activated carbon (Pearlman's catalyst), unreduced, 50% water wet paste (Escat™ 1951) [7440-05-3]	5g	Visit www.strem.com
46-1710	Palladium, 0.6% on activated carbon, 50% water-wet paste (NanoSelect LF 100) [7440-05-3]	5g	See page 40
46-1901	Palladium, 5% on activated peat carbon, reduced, 50% water wet paste (Escat™ 1621) [7440-05-3]	10g	Visit www.strem.com
46-1902	Palladium, 5% on activated wood carbon, reduced, dry (Escat™ 1431) [7440-05-3]	10g	Visit www.strem.com
46-1903	Palladium, 5% on activated wood carbon, reduced, 50% water wet paste (Escat™ 1421) [7440-05-3]	10g	Visit www.strem.com
46-1904	Palladium, 5% on activated wood carbon, unreduced, 50% water wet paste (Escat™ 1471) [7440-05-3]	10g	Visit www.strem.com
46-1905	Palladium, 10% on activated wood carbon, reduced, 50% water wet (Escat™ 1931) [7440-05-3]	10g	Visit www.strem.com
46-1906	Palladium, 10% on activated wood carbon, unreduced, 50% water wet (Escat™ 1921) [7440-05-3]	10g	Visit www.strem.com
46-1951	Palladium, 5% on alumina powder, reduced, dry (Escat™ 1241) [7440-05-3]	5g	Visit www.strem.com

BASF PLATINUM CATALYST KIT

96-6721

BASF Platinum Catalyst Kit

NEW→

Components available for individual sale.

Contains the following:

78-1611	Platinum, 5% on activated wood carbon, reduced, dry (Escat™ 2431) [7440-06-4]	5g	Visit www.strem.com
78-1612	Platinum, 5% on activated wood carbon, reduced, 50% water wet paste (Escat™ 2421) [7440-06-4]	5g	Visit www.strem.com
78-1613	Platinum, 5% on activated carbon, unreduced, 50% water wet paste (Escat™ 2441) [7440-06-4]	5g	Visit www.strem.com
78-1614	Platinum, 3% on activated wood carbon, reduced, 70% water wet paste (Escat™ 2931) [7440-06-4]	5g	Visit www.strem.com
78-1661	Platinum, 5% on alumina powder, reduced, dry (Escat™ 2941) [7440-06-4]	5g	Visit www.strem.com
78-1892	Platinum(IV) oxide hydrate (~80-82% Pt) (99.95+%-Pt) ADAM'S CATALYST [BASF C7018] [1314-15-4]	1g	Visit www.strem.com

New Products Introduced Since Catalog 22

PINAP LIGAND KIT

96-7050

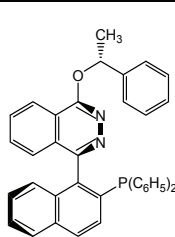
NEW→

PINAP Ligand Kit

for a variety of asymmetric C-C bond formations.
Contains the following:

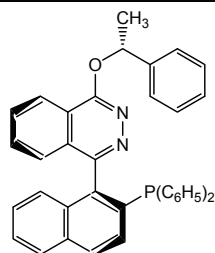
1 kit

Components available for individual sale.



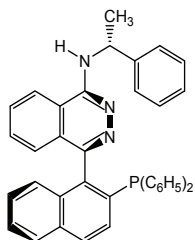
15-1782

250mg



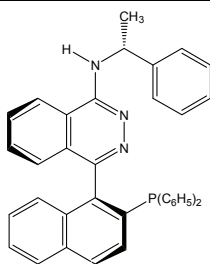
15-1783

250mg



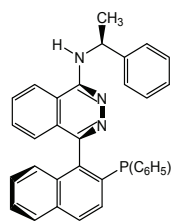
15-1784

250mg



15-1786

250mg



15-1787

250mg

15-1782	(R)-(+)-4-[2-(Diphenylphosphino)-1-naphthalenyl]-N-[(R)-1-phenylethoxy]phthalazine, min. 97% (R,R)-O-PINAP [828927-95-3]	250mg	See page 45
15-1783	(S)-(-)-4-[2-(Diphenylphosphino)-1-naphthalenyl]-N-[(R)-1-phenylethoxy]phthalazine, min. 97% (R,S)-O-PINAP [828927-94-2]	250mg	See page 46
15-1784	(R)-(+)-4-[2-(Diphenylphosphino)-1-naphthalenyl]-N-[(R)-1-phenylethyl]-1-phthalazinamine, min. 97% (R,R)-N-PINAP [828927-97-5]	250mg	Visit www.strem.com
15-1786	(S)-(-)-4-[2-(Diphenylphosphino)-1-naphthalenyl]-N-[(R)-1-phenylethyl]-1-phthalazinamine, min. 97% (R,S)-N-PINAP [828927-96-4]	250mg	Visit www.strem.com
15-1787	(R)-(+)-4-[2-(Diphenylphosphino)-1-naphthalenyl]-N-[(S)-1-phenylethyl]-1-phthalazinamine, min. 97% (S,R)-N-PINAP	250mg	See page 46

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