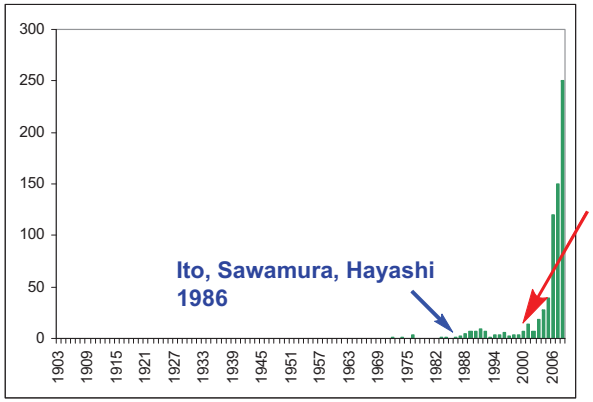
2010

well over 100 groups worldwide are working on **homogeneous** gold-catalyzed reactions



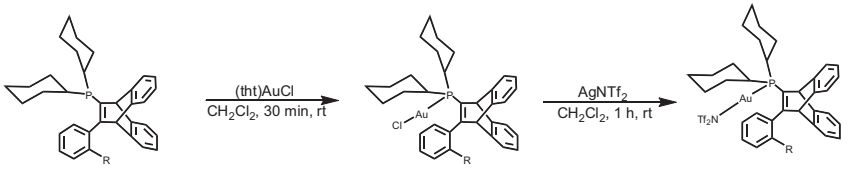
Catalysts
Methodology
Mechanisms
Synthesis

A. S. K. Hashmi, L. Schwarz, J.-H. Choi, T. M. Frost, *Angew. Chem. Int. Ed. Engl.* **2000**, *39*, 2285-2288.

> 350 citations

A. S. K. Hashmi, *Chem. Rev.* **2007**, *107*, 3180-3211.
A. S. K. Hashmi, G. J. Hutchings, *Angew. Chem.* **2006**, *45*, 7896-7936.
A. S. K. Hashmi, *Gold Bull.* **2004**, *37*, 51-65.

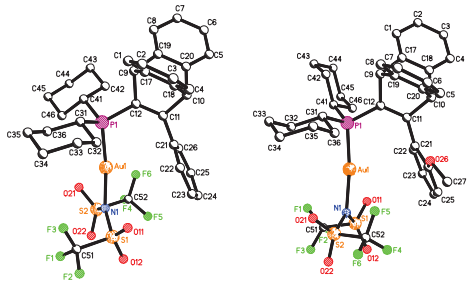
Gold(I) prefers *P* or *NHC* ligands and a *linear* coordination geometry



KITPHOS

Up to 2000 turnovers (0.05 mol% of catalyst)

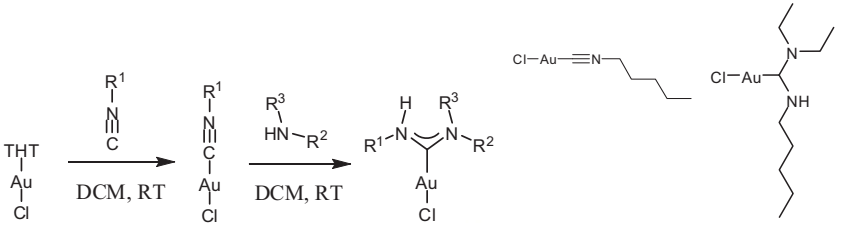
Ito 1986



Raubenheimer 2002

A. S. K. Hashmi, A. Loos, A. Littmann, I. Braun, J. Knight, S. Doherty, F. Rominger, *Adv. Synth. Catal.* **2009**, *351*, 576-582.

Gold(I) prefers *P* or *NHC* ligands and a *linear* coordination geometry



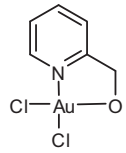
Up to 3000 turnovers with a problematic substrate

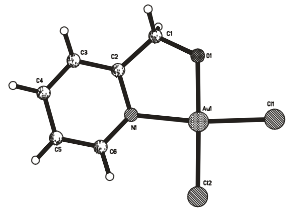
Raubenheimer 2002

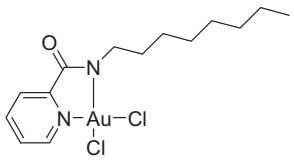
Herrmann 2003

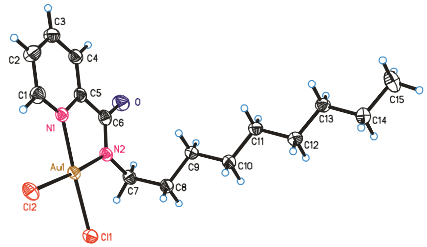
A. S. K. Hashmi, T. Hengst, C. Lothschütz, F. Rominger, *Adv. Synth. Catal.* **2010**, *352*, 1315-1337.

Gold(III) prefers *N* or *O* and a *square-planar* coordination geometry





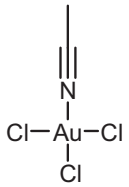


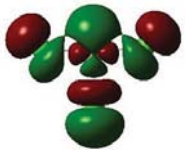


Utimoto 1987

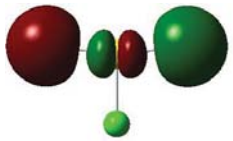
A. S. K. Hashmi, J. P. Weyrauch, M. Rudolph, E. Kurpejovic, *Angew. Chem. Int. Ed.* **2004**, *43*, 6545-6547.

Frontier Orbitals of $AuCl_3$?

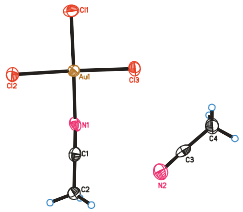




LUMO

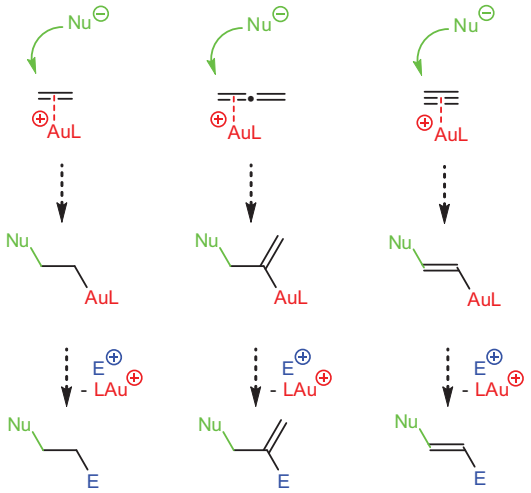


HOMO

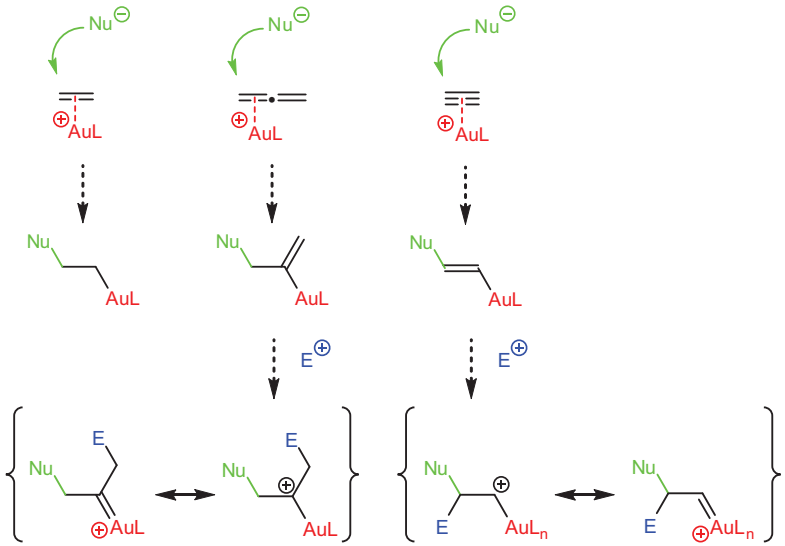


B3LYP with Stuttgart ECP and basis for Au
and 6-31G(d,p) on other atoms
David Willock, Cardiff

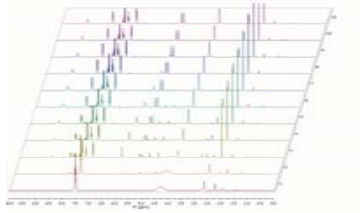
What is the General Reactivity Pattern ?

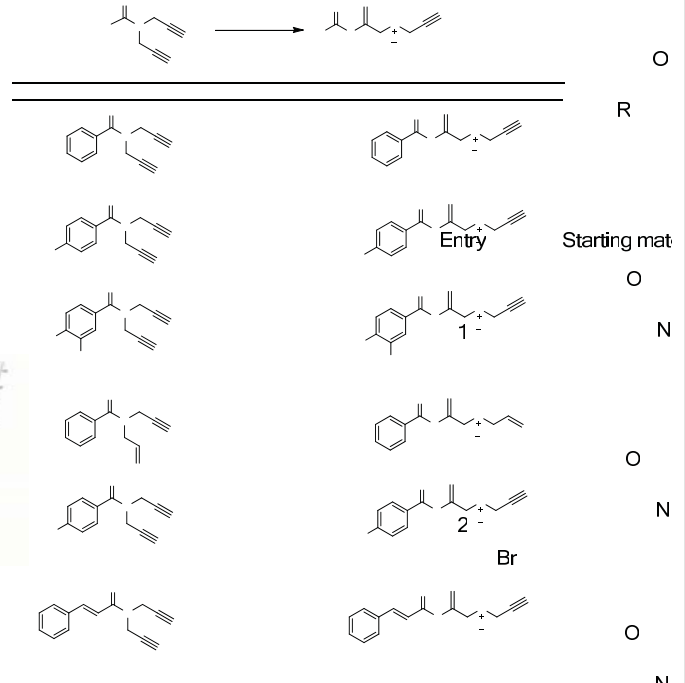


Modification of the Reactivity Pattern

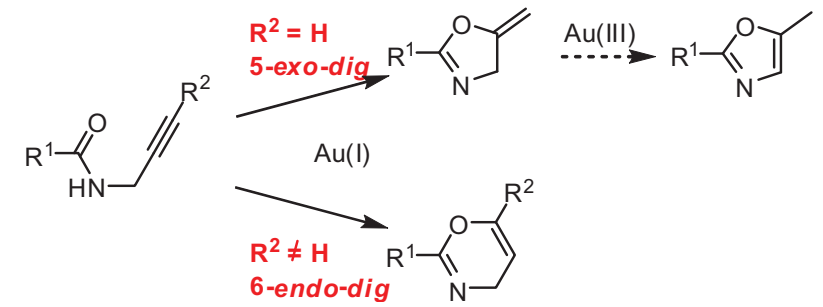


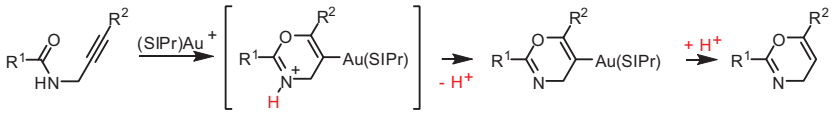
Cyclisation in the presence of water



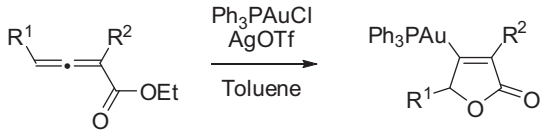


Substituents

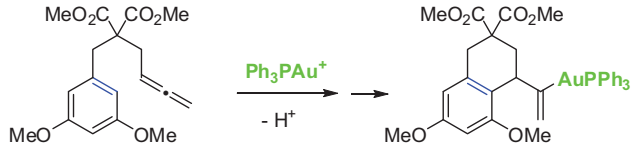




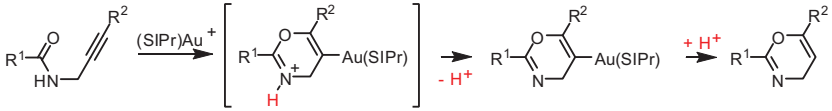
Stable vinylgold intermediates



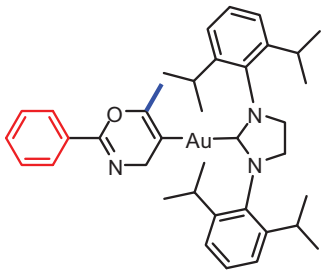
L.-P. Liu, B. Xu, M. S. Mashuta, G. B. Hammond, *J. Am. Chem. Soc.* **2008**, *130*, 17642–17643.

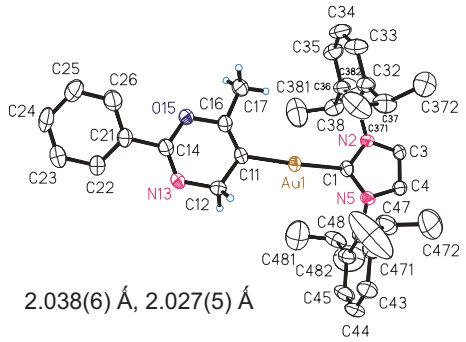


D. Weber, M. A. Tarselli, M. R. Gagné, *Angew. Chem.* **2009**, *121*, 5843-5846; *Angew. Chem. Int. Ed.* **2009**, *48*, 5733-5736.



Substituents



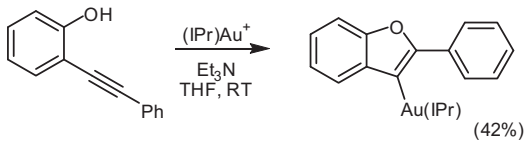


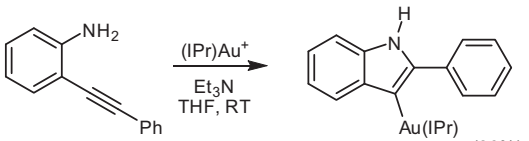
2.038(6) Å, 2.027(5) Å

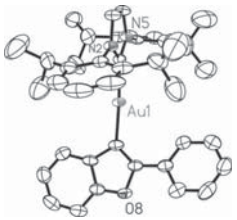
Phenyl, Methyl	63%
Adamantyl, Methyl	58%
Adamantyl, Butyl	71%
2,5-Dimethylfur-3-yl, Methyl	62%

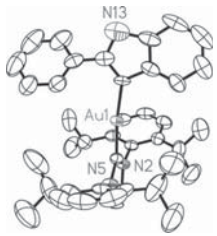
A. S. K. Hashmi, A. Schuster, F. Rominger, *Angew. Chem. Int. Ed.* **2009**, *48*, 8247-8249.

Stable organogold intermdiates of other reactions









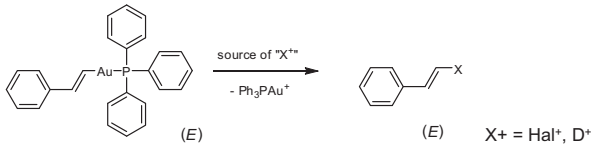
A. S. K. Hashmi, T. D. Ramamurthi, F. Rominger, *Adv. Synth. Catal.* **2010**, *352*, 971-975.

? Other Electrophiles ?

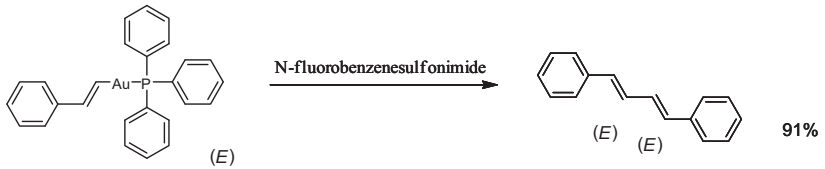
A. Buzas, F. Gagosz, *Org. Lett.* **2006**, *8*, 515-518. A. Buzas, F. Gagosz, *Synlett* **2006**, 2727–2730; A. Buzas, F. Istrate, F. Gagosz, *Org. Lett.* **2006**, *8*, 1958–2006. S. F. Kirsch, *Angew. Chem. Int. Ed.* **2007**, 46, 2310–2313. L. Zhang, *Org. Lett.* **2007**, *9*, 2147–2150. B. Crone, S. F. Kirsch, *J. Org. Chem.* **2007**, *72*, 5435–5438. S. K. Bhargava, F. Mohr, M. A. Bennett, L. L. Welling, A. C. Willis, *Organometallics* **2000**, *19*, 5628–5635. Z. Shi, C. He, *J. Am. Chem. Soc.* **2004**, *126*, 3596–13597.

Hal^+

J. P. Weyrauch, A. S. K. Hashmi, A. Schuster, T. Hengst, S. Schetter, A. Littmann, M. Rudolph, M. Hamzic, J. Visus, F. Rominger, W. Frey, J. W. Bats, *Chem. Eur. J.* **2010**, *16*, 956-963.



A. S. K. Hashmi, T. D. Ramamurthi, F. Rominger, *J. Organomet. Chem.* **2009**, *694*, 592-597.



A. S. K. Hashmi, T. D. Ramamurthi, F. Rominger, *J. Organomet. Chem.* **2009**, *694*, 592
submitted on 17th October 2008

G. Zhang, Y. Peng, L. Cui, L. Zhang, *Angew. Chem. Int. Ed.* **2009**, *48*, 3112
submitted on 1st February 2009

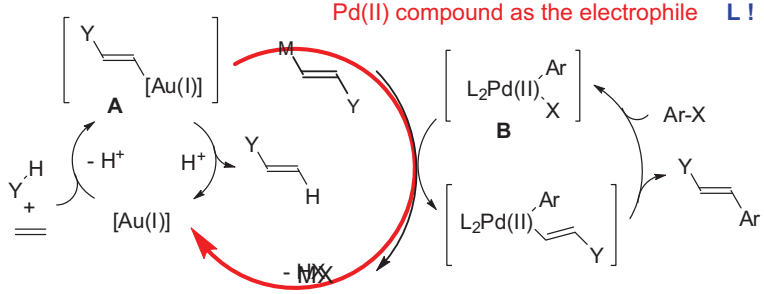
L. Cui, G. Zhang, L. Zhang, *Bioorg. Med. Chem. Lett.* **2009**, *19*, 3884
submitted on 17th February 2009

M. N. Hopkinson, A. Tessier, A. Salisbury, G. T. Giuffredi, L. E. Combettes, A. D. Gee, V. Gouverneur, *Chem. Eur. J.* **2010**, *16*, 4739

$(R^1)^{--}$ + $(R^2)^{--}$ + ox
--> R^1-R^2 + …

? The Future ?

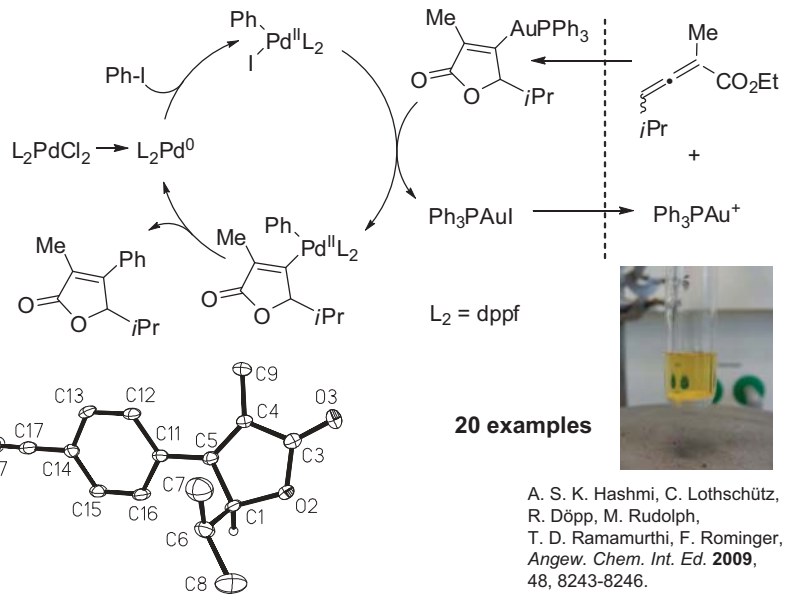
Pd(II) compound as the electrophile **L !**



- saves a C-H activation
- orthogonality of Au/Pd
- adds another dimension to gold catalysis

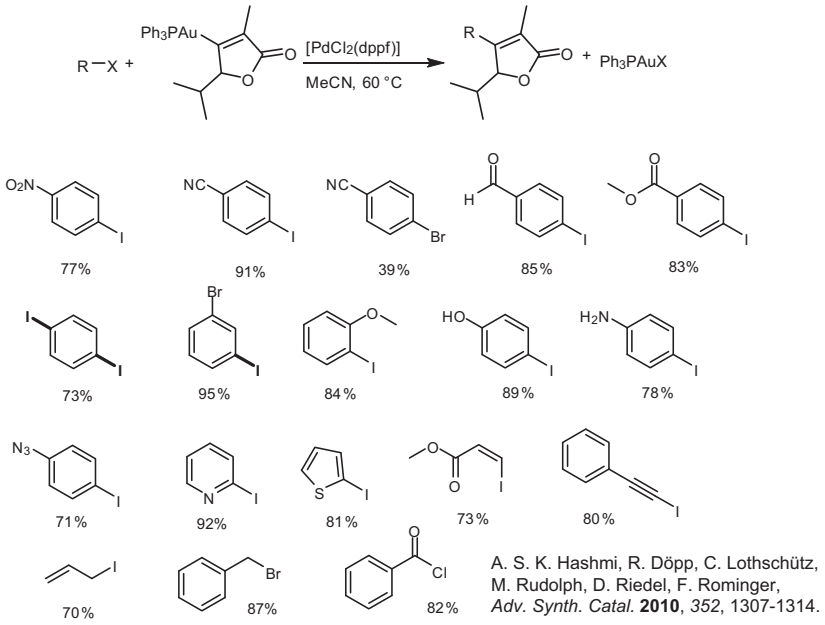
A. S. K. Hashmi, C. Lothschütz, R. Döpp, M. Rudolph, T. D. Ramamurthi, F. Rominger, *Angew. Chem. Int. Ed.* **2009**, 48, 8243-8246.

L.-P. Liu, B. Xu, M. S. Mashuta, G. B. Hammond, *J. Am. Chem. Soc.* **2008**, *130*, 17642–17643.

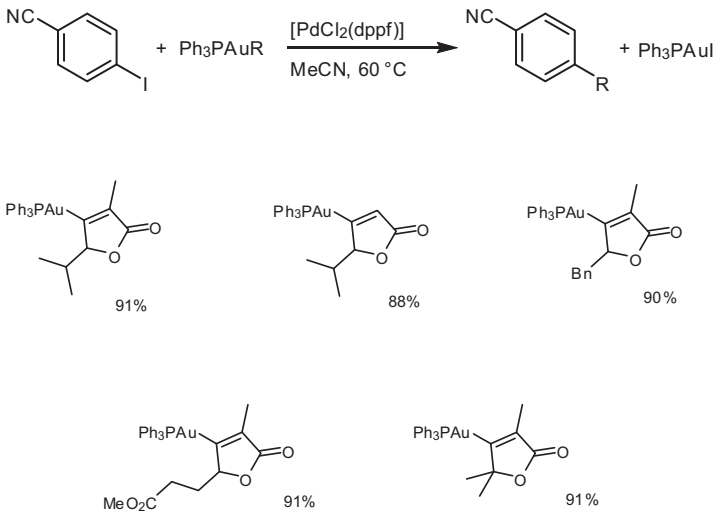


20 examples

A. S. K. Hashmi, C. Lothschütz, R. Döpp, M. Rudolph, T. D. Ramamurthi, F. Rominger, *Angew. Chem. Int. Ed.* **2009**, 48, 8243-8246.

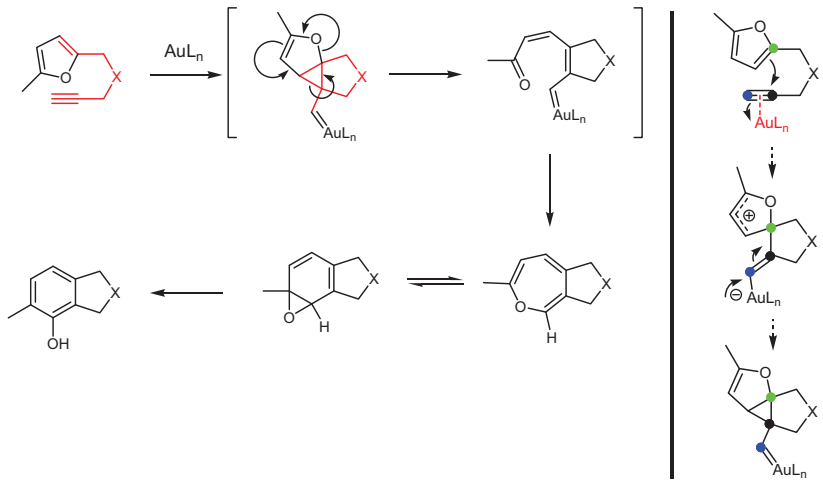


A. S. K. Hashmi, R. Döpp, C. Lothschütz, M. Rudolph, D. Riedel, F. Rominger, *Adv. Synth. Catal.* **2010**, *352*, 1307-1314.



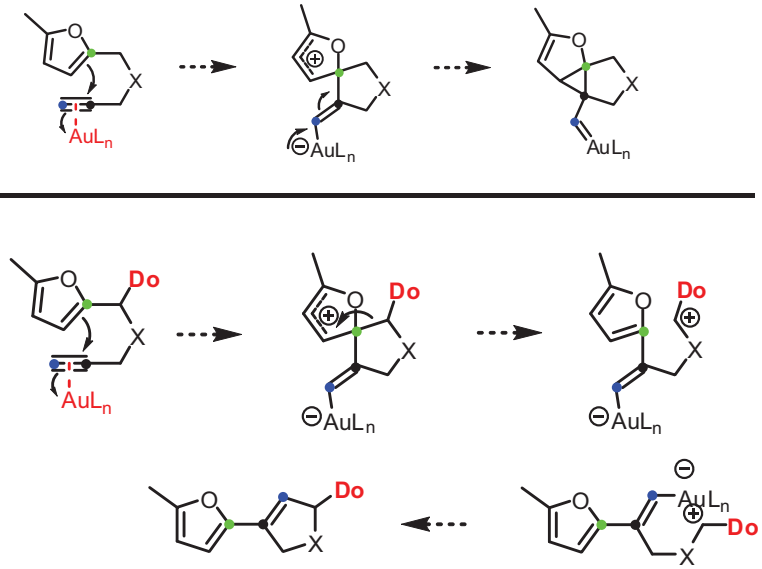
A. S. K. Hashmi, R. Döpp, C. Lothschütz, M. Rudolph, D. Riedel, F. Rominger, *Adv. Synth. Catal.* **2010**, *352*, 1307-1314.

The Gold-Catalyzed Phenol Synthesis: The Mechanistic Picture

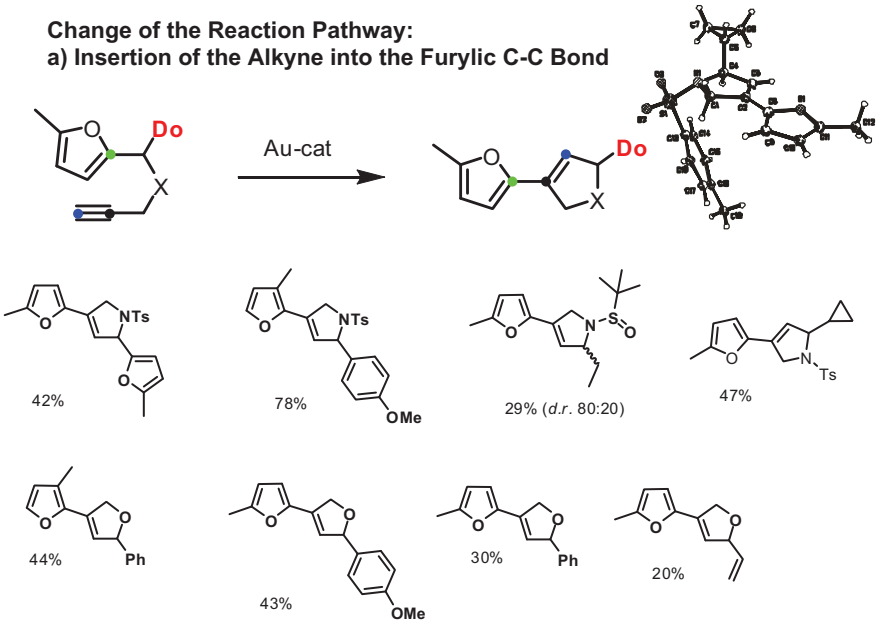


B. Martín-Matute, D. J. Cardenas, A. M. Echavarren, *Angew. Chem. Int. Ed.* **2001**, *40*, 4754-4757.
A. S. K. Hashmi, M. Rudolph, J. P. Weyrauch, M. Wölfle, W. Frey, J. W. Bats, *Angew. Chem. Int. Ed.* **2005**, *44*, 2798-2801.

Change of the Reaction Pathway:
a) Insertion of the Alkyne into the Furylic C-C Bond



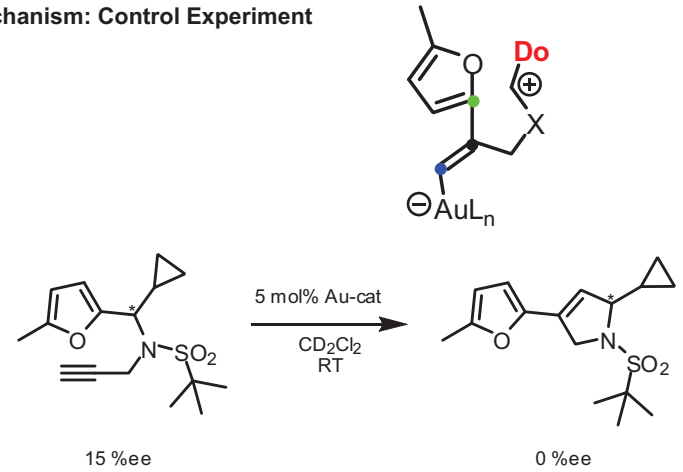
Change of the Reaction Pathway:
a) Insertion of the Alkyne into the Furylic C-C Bond



S. Schäfer, S. Panjankastan, T. Hengst, A. S. K. Hashmi, unpublished results.

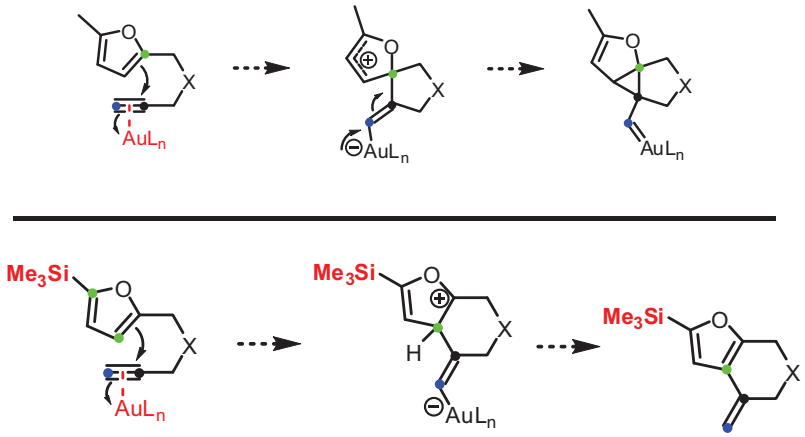
Change of the Reaction Pathway:
a) Insertion of the Alkyne into the Furylic C-C Bond

Mechanism: Control Experiment

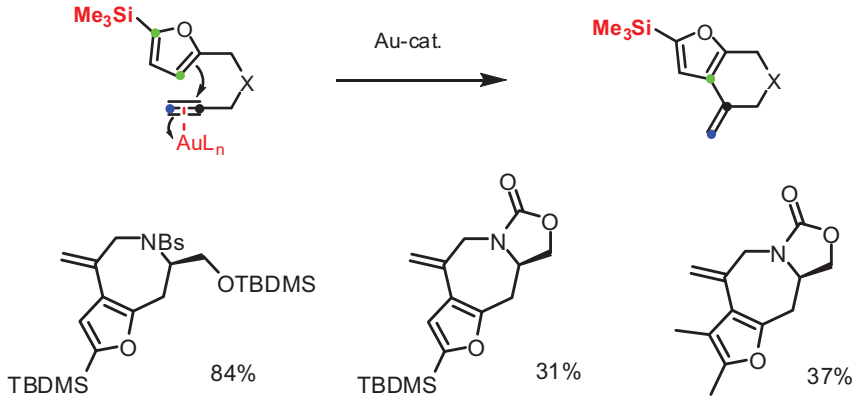


T. Hengst, A. S. K. Hashmi, unpublished results.

Change of the Reaction Pathway:
b) Hydroarylation of the Furan

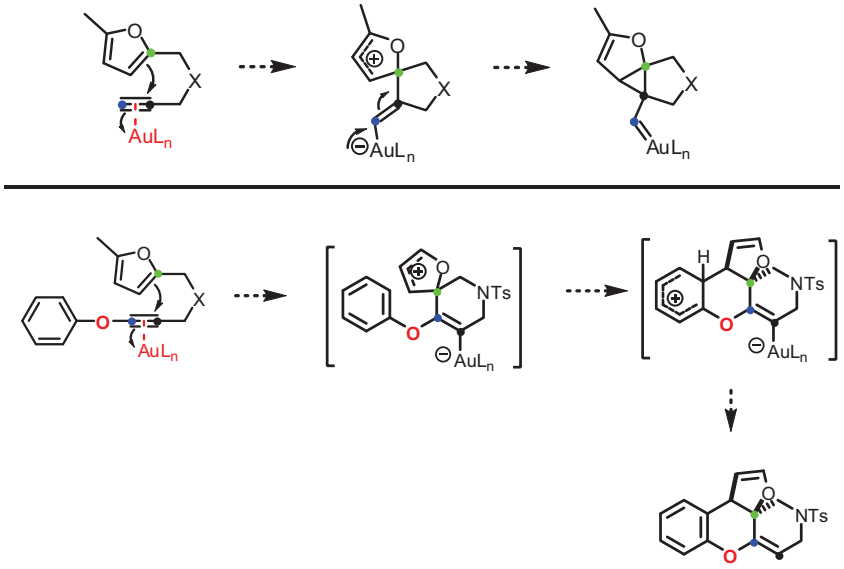


Change of the Reaction Pathway:
b) Hydroarylation of the Furan



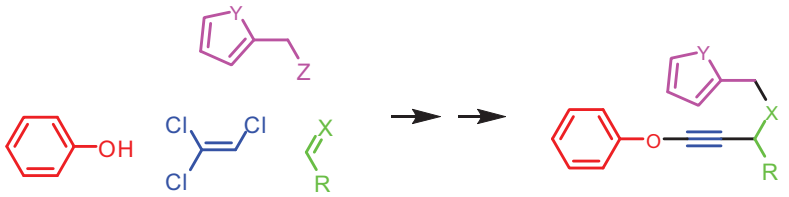
A. S. K. Hashmi, P. Haufe, C. Schmid, A. Rivas Nass, W. Frey, *Chem. Eur. J.* **2006**, *12*, 5376-5382.

Change of the Reaction Pathway:
c) Polycyclic Compounds I



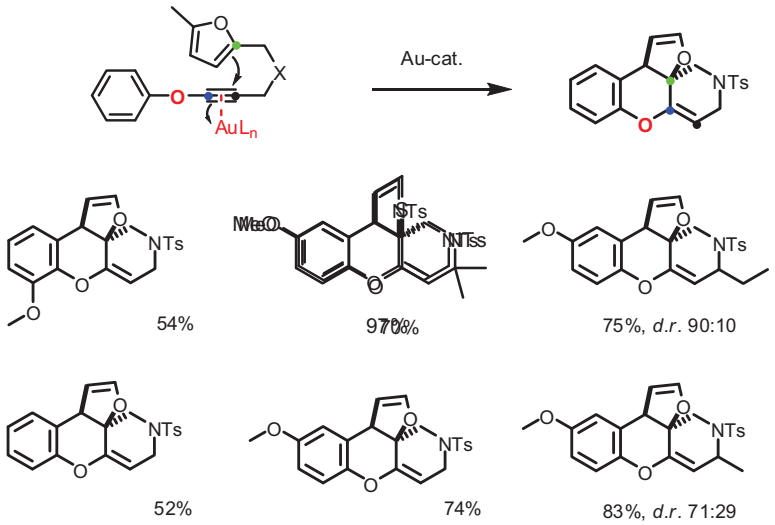
Change of the Reaction Pathway:
c) Polycyclic Compounds I

Synthesis of the Substrates



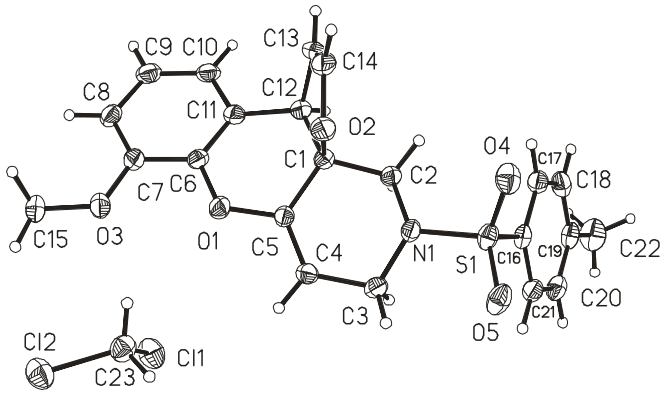
X, Y = O, NR'

Change of the Reaction Pathway:
c) Polycyclic Compounds I

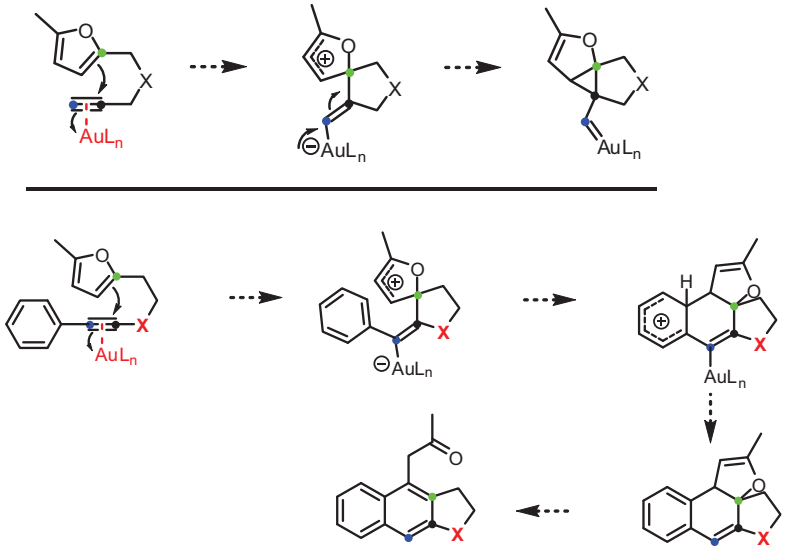


A. S. K. Hashmi, M. Rudolph, J. Huck, W. Frey, J. W. Bats, M. Hamzic, *Angew. Chem.* **2009**, *48*, 5848-5852.

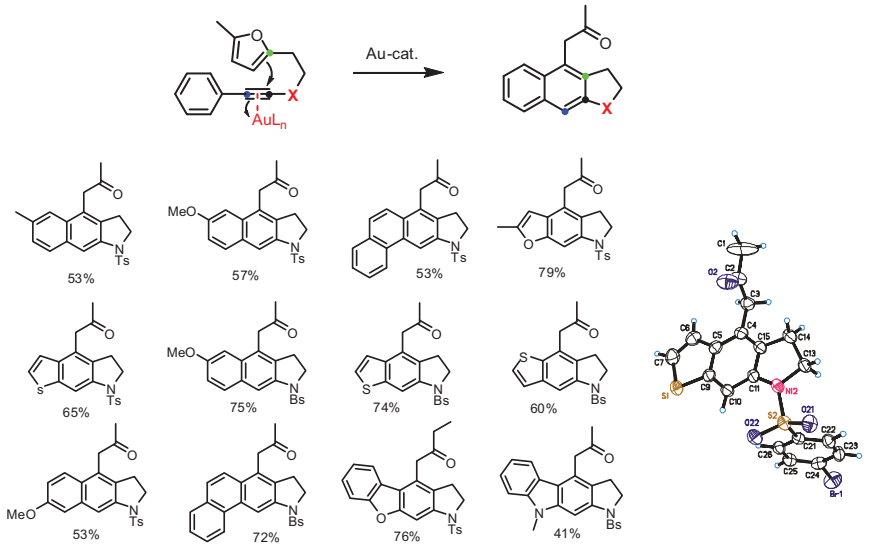
Change of the Reaction Pathway:
c) Polycyclic Compounds I



Change of the Reaction Pathway:
d) Polycyclic Compounds II

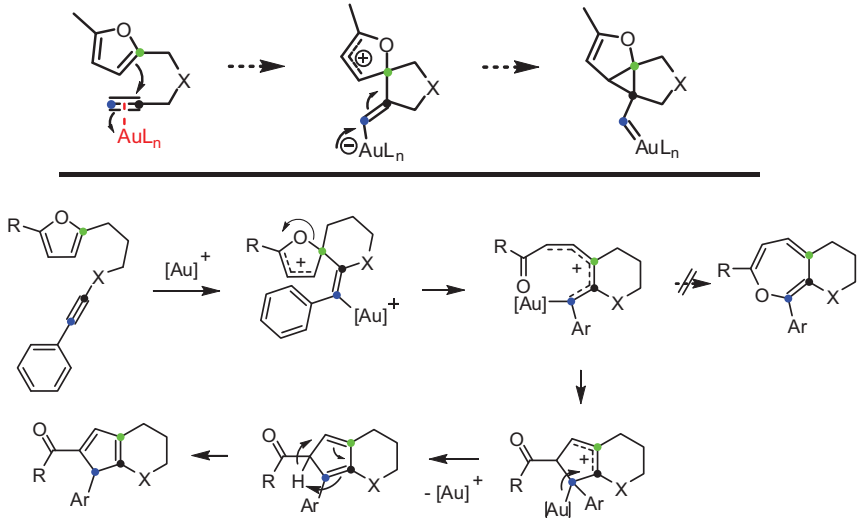


Change of the Reaction Pathway:
d) Polycyclic Compounds II

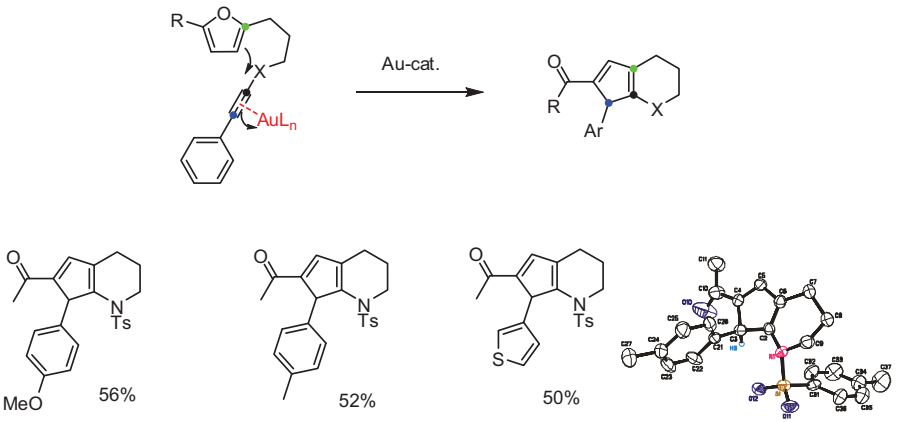


A. S. K. Hashmi, S. Panjankastan, M. Rudolph, F. Rominger, W. Frey, *Adv. Synth. Catal.* **2009**, *351*, 2855-2875.

Change of the Reaction Pathway:
e) Polycyclic Compounds III

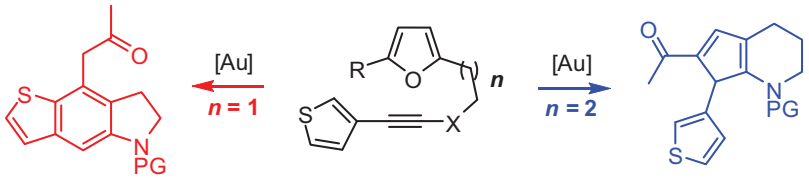


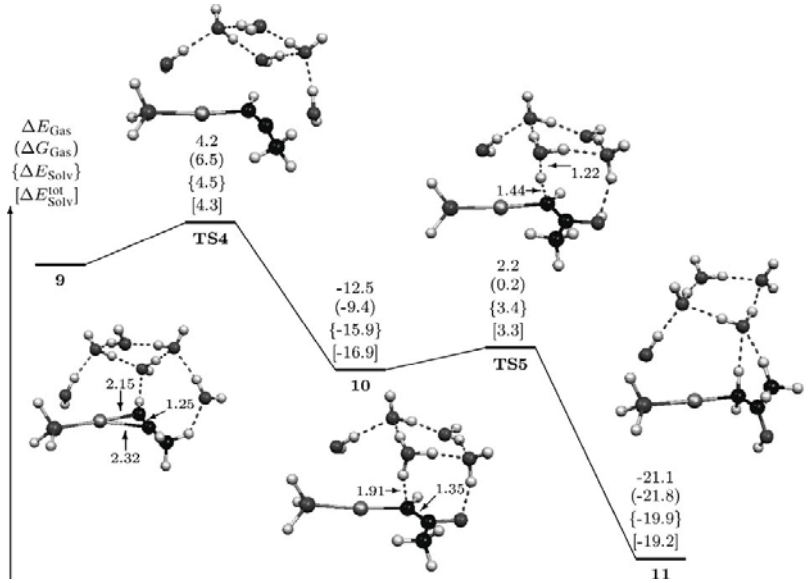
Change of the Reaction Pathway:
d) Polycyclic Compounds II

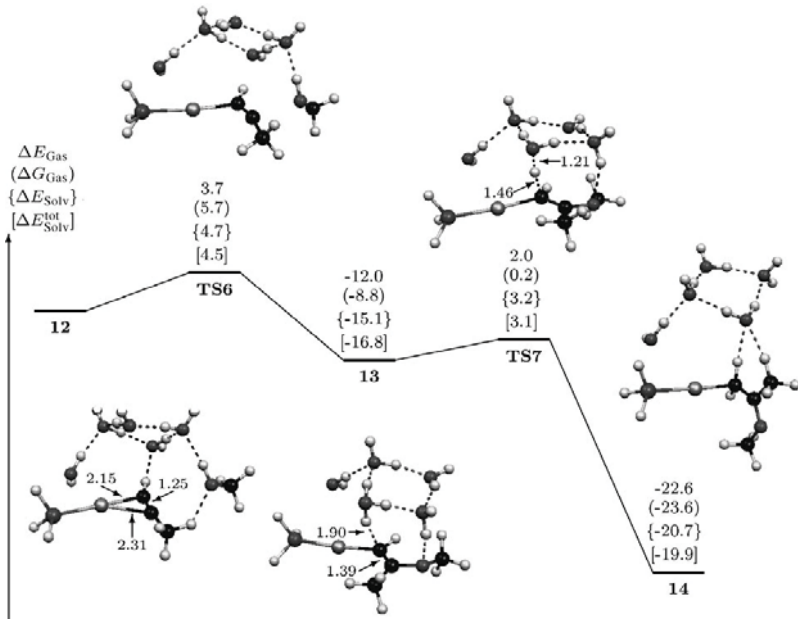


A. S. K. Hashmi, S. Panjankastan, M. Rudolph, F. Rominger, W. Frey, *Adv. Synth. Catal.* **2009**, *351*, 2855-2875.

Change of the Reaction Pathway:
f) Polycyclic Compounds IV: Comparison of II and III







Summary

1. Gold is not too expensive for catalysis
2. Activation for Nucleophilic Attack
3. Highest Reactivity
4. No Precautions, Water and Air Tolerated
5. No Paramagnetic Species
6. „Isohypsic“ Reactions
7. Fast Proto-Desauration

A. S. K. Hashmi,
Chemistry in Australia
2009, *May*, 7-10.