

For Palladium-Catalysed C–N And C–C Cross-Couplings.

Air and moisture insensitive auxiliary ligands for highly efficient palladium catalysts. These **ultra - low loading (high TONs or TOFs)** catalysts have shown excellent activity in **Suzuki cross - coupling with aryl bromides and chlorides, Heck vinylation, Heck - Sonogashira alkynylation** and **allylic amination** of allyl acetates (**Tsuji – Trost** type reactions). Low loadings of the catalysts ensure minimal contamination of the final compounds with palladium and simplify the purification procedures. High stability of the allows to store them for unlimited time without special precautions.

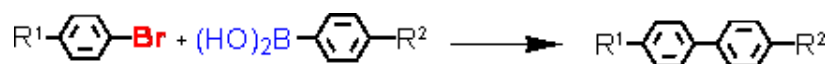
<p>Tetraphos Fc(P)₄</p>	<p>Triphos Fc(P)₃</p>	<p>Triphos Fc(P)₂P^{iPr}</p>
EN400-15231	EN400-15232	EN400-15233
<p>Tetraphos Fc(P)₂(P')₂</p>	<p>Diphos Fc(P)₂</p>	<p>Diphos Fc(P^{FuMe})₂ R = </p>
EN400-15234	EN400-15235	EN400-15236

Ligands are available in milligram and multigram quantities.

EXAMPLES & NOTES:

(J.-C. Hierso et al. *Organometallics* (2003), 22(22), 4490-4499.)

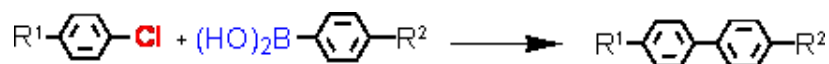
- **Suzuki cross-coupling** with aryl bromides at **ultra-low** catalyst loadings (L = Tetraphos Fc(P)₄ **EN400-15231**)



R ¹	R ²	Ratio S/Cat.	Yield, %
C(=O)Me	H	100000	100 (94) ^a
CN	H	100000	100 (87) ^a
CF ₃	H	100000	100
OMe	H	100000	77
OMe	H	10000	100 (92) ^a

a - isolated yield, conditions: 1 Pd / 1 Tetraphos Fc(P)₄: 10⁻² - 10⁻⁴ mol%; DMF or xylene, K₂CO₃, 130 °C, 20h.

- **Suzuki cross-coupling** with aryl chlorides (L = Tetraphos Fc(P)₄ **EN400-15231**)

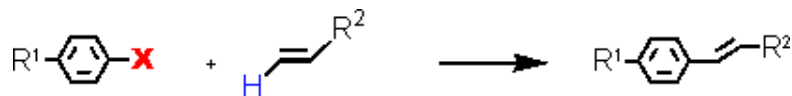


R ¹	R ²	Ratio S/Cat.	Yield, %
C(=O)Me	OMe	1000	98 (88) ^a

C(=O)Me	OMe	10000	74
CN	OMe	1000	89 (83) ^a

a - isolated yield, conditions: 1 Pd / 1 Tetracos Fc(P)₄ : 10⁻¹ - 10⁻² mol%; DMF or xylene, K₂CO₃, 130 °C, 20h.

- **Heck reaction at ultralow catalyst loadings (L = Tetracos Fc(P)₄ EN400-15231)**



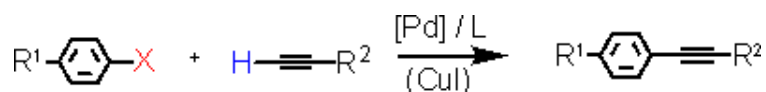
Aryl Halide	Alkene	Ratio S/Cat.	Yield, %	Time, h
PhI	<i>n</i> -BuOCOCH=CH ₂	1000 000	100 (85) ^a	48
4-MeOC ₆ H ₄ Br	<i>n</i> -BuOCOCH=CH ₂	10 000	100 (88) ^a	48
4-MeOC ₆ H ₄ Br	C ₆ H ₅ CH=CH ₂	100 000	65 ^a	20
4-CH(O)C ₆ H ₄ Br	<i>n</i> -BuOCH=CH ₂	250	100 (83) ^a	20
4-CH(O)C ₆ H ₄ Br	<i>n</i> -BuOCH=CH ₂	1000	41 ^a	20

a - isolated yield, conditions: 1 Pd / 1 Tetracos Fc(P)₄, Xylene, K₂CO₃, 130 °C.

- **Alkynylation of aryl halides (Heck-Sonogashira reaction) under low (10⁻¹ to 10⁻⁴ mol%) catalyst loadings in the presence of a Triphos Fc(P)₂PiPr EN400-15233 with TONs up to 250000. Copper-free coupling using phenyl- acetylene is also accessible in good yield.**

J.-C. Hierso, V. Ivanov et al., *Organic Letters* (2004), 6(20), 3473-3476.

H. Doucet, J.-C. Hierso, *Angewandte Chemie International Edition* (2007), 46, 834-871.



Aryl Halide	Alkyne	Ratio S/Cat.	Yield, %
PhI	phenylacetylene	100000	95
4-Bromoacetophenone	phenylacetylene	100000	94
4-Bromobenzonitrile	phenylacetylene	10000	89
4-Chlorobenzonitrile	phenylacetylene	250	86 ^a
4-Bromoanisole	phenylacetylene	250	93
4-Bromoacetophenone	but-1-yn-4-ol	250	92 ^b

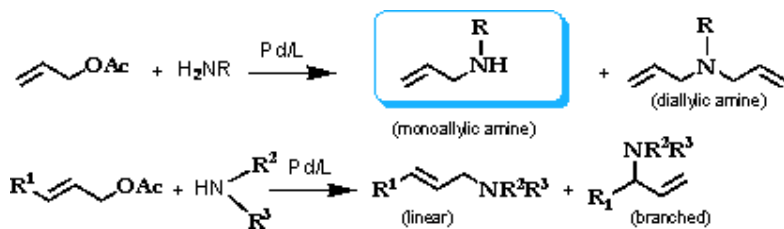
^aReaction performed without CuI.

^bReaction performed at 100 °C / Conditions: catalyst {Pd(C₃H₅)Cl}₂/Triphos Fc(P)₂PiPr 1/2, aryl halide (1 mmol), alkyne (2 mmol), CuI (0.05 mmol), K₂CO₃ (2 mmol), DMF, 130 °C, 20 h, isolated yields.

- **Selective Amination of allylic acetates** under low catalyst loadings in the presence of ferrocenyldiphosphine *Diphos Fc(P^{FuMe})₂* EN400-15236

J.-C. Hierso et al. *Advanced Synthesis and Catalysis* (2005), 347(9), 1198-1202.

J.-C. Hierso, H. Doucet et al. *Tetrahedron* (2005), 61, 9759-9766.



Acetate	Amine	Ratio S/Cat.	Conditions	Conversion, %	Selectivity	TOF (h ⁻¹)
Allyl acetate	aniline	100	Rt, 1h	100	96/4	10000
Allyl acetate	piperidine	10000	Rt, 1h	100	-	5000
Allyl acetate	morpholine	10000	Rt, 2h	85	100	4250
Allyl acetate	diisopropylamine	1000	80 °C 2h	96	100	480
Hex-2-en-1-yl acetate	pyrrolidine	1000	50 °C, 20h	100	93/7(lin/br)	-
Hex-2-en-1-yl acetate	morpholine	1000	50 °C, 20h	98	94/6(lin/br)	-
Cinnamyl acetate	pyrrolidine	1000	50 °C, 20h	100	94/6(lin/br)	2600
Cinnamyl acetate	morpholine	1000	50 °C, 20h	100	93/7(lin/br)	4800
Cinnamyl acetate	diethylamine	1000	Rt, 20h	100	94/6(lin/br)	7600
Geranyl acetate	morpholine	1000	80 °C, 3h	100	98	33

Catalyst {Pd(C₃H₅)Cl}₂ / *Diphos Fc(P^{FuMe})*₂ Conditions: S/C = 250-10000, T = 25°C-50 °C, 2 equiv. amine, 1 to 20 h.

As reference: see also:

J.-C. Hierso, R. Smaliy et al., *Chemical Society Reviews* (2007), 36, 1754-1769.