Reduction of Aryl Mesylates Catalyzed by Nickel Complexes

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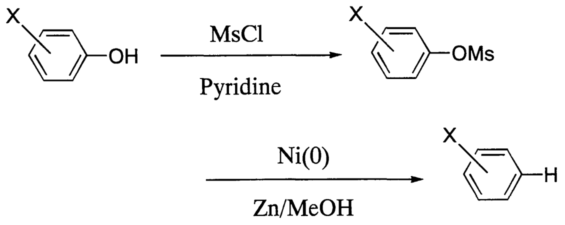
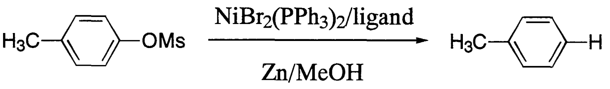
Aryl mesylates were found to be deoxygenatively reduced into the corresponding aromatic hydrocarbons by using nickel(0)-dppb/PPh_3 catalyst with zinc powder and an alcohol as a hydrogen donor.

Aryl triflates (aryl trifluoromethanesulfonates) were useful intermediates for transformations of phenolic hydroxyl group and have been subjected to various transition metal-mediated reactions.[1] However, alternative aryl sulfonates besides triflates such as mesylates (methanesulfonates) and tosylates (*p*-toluenesulfonates), which were thermally more stable and much less expensive, have been recognized less reactive in various transition-metal catalyzed transformations. Recently, Percec *et al* found that Ni(0)-phosphine complexes underwent oxidative addition to the sp^2carbon-oxygen bond of aryl mesylates and catalyzed some important organic transformations such as homo- and cross-coupling, and nucleophilic substitution reactions.[2-4] We previously reported Ni(0)-mediated reduction of aryl triflates to the corresponding aromatic hydrocarbons with zinc powder in the presence of hydrogen donor such as methanol.[5] This reaction provided convenient two step procedure for the substitution of phenolic hydroxyl group into the hydrogen atom, which was one of most difficult transformation in classical synthetic methods. Here, we would like to report a more convenient method for the Ni(0)-mediated reduction of the phenolic hydroxyl group using aryl mesylates.



Reduction of *p*-tolyl mesylate to toluene was carried out in the presence of excess amount of zinc powder and methanol as hydrogen donor. $NiBr_2(PPh_3)_2$/dppp (dppp = 1,3-bis(diphenylphosphino)propane) mixed ligand system, which was most effective for the reduction of corresponding triflates as reported previously,[3] was less effective in the case of the mesylate. Thus, various reaction conditions including additional ligand, solvents, and reaction temperature were reinvestigated by using 10 mol% of Ni complex in the presence of excess amount of KI, Zn powder and methanol. As shown in Table 1, the combination of $NiBr_2(PPh_3)_2$ and dppb (dppb = 1,4-bis(diphenylphosphino)butane) gave the best result in investigated Ni-ligand systems. Aprotic solvents such as *N,N*-dimethylacetoamide (DMAc), *N,N*-dimethylformamide (DMF), or *N*-Methylpyrrolidinone (NMP) could be used for the reduction. Interestingly, homo-coupling reaction as expected in the Ni-catalyzed reactions under similar conditions[2,6] was completely suppressed by the addition of methanol.

Table 1. Reduction of *p*-tolyl mesylate catalyzed by nickel complexes[a]



Ligand	Solvent	Yield of Toluene/%[b]
PPh_3	DMF	48
dppe	DMF	33
dppp	DMF	48
dppf	DMF	19
dppb	DMF	82
dppb	DMAc	88
dppb	NMP	81

[a] Reactions were carried out by using 1.0 mmol of *p*-tolyl mesylate in 2 ml of 30% methanol mixed solvents for 16 h at 50 ^oC. The molar ratio of substrate/ $NiBr_2(PPh_3)_2$/Zn/KI is 1/0.1/1.5/1.5. The molar ratio of Ni/ligand is 1/1 for dppe, dppp, dppf, and dppb, or 1/2 for PPh_3. [b] Yields were determine by GLC.

The reduction of various aryl mesylates catalyzed by Ni-dppb system were carried out by using methanol or ethanol as the hydrogen donor in DMAc, DMF, or NMP as the solvent. A typical experimental procedure is as follows: A mixture of 4-methoxycarbonylphenyl mesylate (1.0 mmol), $NiBr_2(PPh_3)_2$ (0.03 mmol), dppb (0.03 mmol), KI (1.5 mmol), and zinc powder (1.5 mmol) in 1 ml of methanol/DMF (30 vol%) was stirred for 16 h at 50 ^oC under nitrogen atmosphere. The resultant mixture was chromatographed on a silica-gel column using dichloromethane as an eluent, affording methyl benzoate (0.87 mmol, 87%).

The best results for each aryl mesylates obtained by similar procedures were shown in Table 2. The reactions readily proceeded to afford the corresponding reduction products in excellent to good yields with intact of functional groups.[5] Among aryl mesylates investigated, 4-methoxycarbonylphenyl mesylate was substantially most reactive, and gave 96% yield (by GLC) of reduction product even in the higher substrate/Ni ratio (3 mol% catalyst). The yield of the reduction product, however, was essentially independent on the electronic properties of the aryl moiety. Furthermore, the reaction also seems to be insensitive toward steric conditions around the reaction center. Thus, none of *o*-substituent of substrates lower the reaction yields seriously. These characteristics would make the present reaction versatile and convenient.

Table 2. Reduction of varios aryl mesylates[a]

$ArOSO_2CH_3$ (Ar =)	Solvent	Alcohol(vol%)	Yield/%[b]	
4-NCPh-	DMF[c,d,e]	MeOH (30)	(83)	68
4-$CH_3C(O)Ph$-	DMF	EtOH (20)	(76)	
4-$CH_3OC(O)Ph$-	DMF[c,e]	MeOH (30)	(96)	87
2-$CH_3OC(O)Ph$-	DMF	EtOH (20)	(81)	
4-CH_3OPh-	NMP	EtOH (30)	(85)	65
2-CH_3OPh-	DMF	MeOH (30)	(74)	
4-C_6H_5Ph-	DMAc	EtOH (20)	(97)	88
2- C_6H_5Ph-	DMF	MeOH (30)	(99)	
2-naphtyl-	DMF[d]	MeOH (30)	(99)	78
	DMF[d,f]	MeOD (30)	(98)	

[a] Reactions were carried out by using 1.0 mmol of aryl mesylates at 50 °C for 16 h in 2 ml of mixed solvent. The molar ratio of substrate/$NiBr_2(PPh_3)_2$/dppb/Zn/KI is 1/0.1/0.1/1.5/1.5. [b] Isolated yields. The values in the parentheses were determined by GLC. [c] Solvent 1 ml. [d] Dppf was used for ligand. [e] The molar ratio of substrate/ $NiBr_2(PPh_3)_2$/dppb/Zn/KI is 1/0.03/0.03/1.5/1.5. [f] Deuterium content of the product determined by GC/MS was >93%.

Another interesting aspect of the present reaction is an application of the deuteration of aromatic hydrocarbons. As shown in the reaction of 2-naphtyl mesylate using CH_3OD, the deuterium atom of methanol-d_1 is incorporated into the aromatic hydrocarbon core. This result indicates that the reaction could be use as an alternative method for the site-selective deuteration on the aromatic ring.

Thus, these procedure affords an alternative and more convenient method for the deoxygenative reduction of phenolic compounds and for deuteration of aromatic ring.

References and Notes

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7 The present reaction could not be applied for nitrophenols because of irrevarsible decomposition of low valent nickel complex and nitro group. See, R. S. Berman and J. K. Kochi, *Inorg. Chem.*, **19**, 248 (1980).