

Iron Catalyzed C-C Coupling Reactions

Mechanistic Investigations

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Abstract

The mechanism of the iron catalyzed cross coupling of aryl electrophiles with alkyl Grignard reagents was studied. The reaction proceeds via a rate-limiting oxidative addition of the aryl halide to an Fe(I) complex generated *in situ*. A transmetalation from an aryl Grignard reagent occurs either before or after the oxidative addition. An exergonic reductive elimination closes the cycle, yielding the cross coupled product and regenerates the Fe(I) from Fe(III). Added ligands and dilution increases the stability of the active catalyst. The reaction can take place at dry ice temperature. Initial rate studies indicated that high concentrations of any reagent can lead to complete or partial catalyst deactivation. Under strongly reducing conditions, iron seems to form less active complexes that only slowly re-enter the catalytic cycle.

The iron catalyzed cross coupling of alkyl electrophiles with aryl Grignard reagents follows the same mechanism as the aryl electrophile – alkyl Grignard coupling. With the more weakly reducing aryl Grignards, the iron catalyst is stable in diethyl ether without additives. The nature of the active catalyst has been under debate. In the couplings with aryl Grignard reagents, the active catalyst is an Fe(I) species. Fe(I) complexes are stable in ether, and they are active catalysts. The active iron catalyst has a spin state of $S=3/2$, even though the precatalytic Fe(III) salts have a high spin state ($S=5/2$). The spin change occurs after the first transmetalation, when the strong ligand field of the aryl group raises the energy of one d-orbital, inducing an electron pairing event.

Keywords: iron, homogenous catalysis, cross coupling, C-C bond formation, reaction mechanisms, kinetic investigations, competitive Hammett study, density functional theory