

PRF#: 58326-UR3

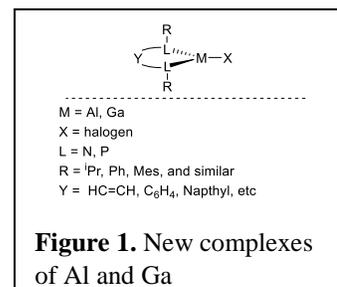
Title: Development of Group XIII Compounds with Weakened Metal-Halide Bonds for use in Transmetalation Reactions and Dual Catalyst Systems for the Functionalization of Alkanes

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Narrative Report

Overview:

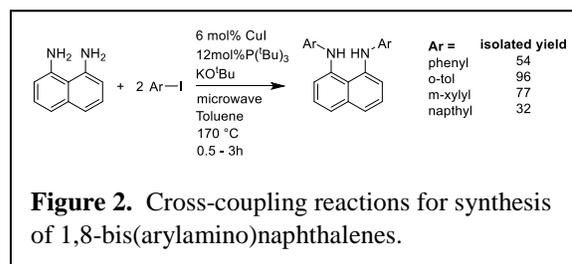
The overall goal of this project is to see if new transmetalations reactions can be designed from first principles and the careful manipulation of bond strengths. The project aims to probe if attenuating metal halide bond strengths in Al and Ga compounds can lead to thermodynamically favorable transmetalations reactions with transition metal organometallic species. Ligands featuring available lone pairs may participate in pi-bonding with the empty p orbital of trigonal planar Al and Ga compounds thus weakening the group XIII metal-halide bond through repulsion of filled orbitals. To this end, new Al and Ga compounds will be synthesized from rigid chelating secondary phosphido- and secondary amido-ligands (**Figure 1**). The attenuation in bond strength will then be measured and transmetalation activity assessed.



Progress:

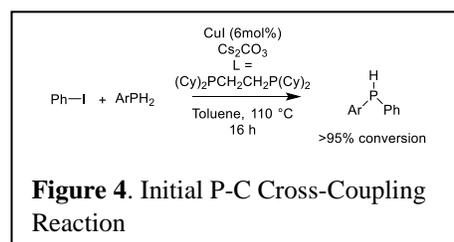
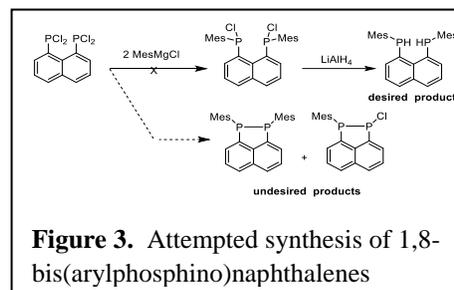
The first year of PRF funding focused largely on ligand synthesis. Our initial focus was on the synthesis of 1,8-bis(arylamino)naphthalenes and 1,8-bis(arylphosphino)naphthalenes.

1,8-bis(arylamino)naphthalenes: Published routes to 1,8-bis(arylamino)naphthalenes are multi-step and, in our hands, give poor yields. As the topic of an undergraduate honor's thesis, a single undergraduate student was tasked with screening for cross-coupling conditions to make 1,8-bis(arylamino)naphthalenes directly from 1,8-diaminonaphthalene. After screening various copper-catalyzed and palladium-catalyzed cross-coupling conditions, a system that gives high conversions to N,N'-disubstituted products and moderate to high isolated yields for a variety of 1,8-bis(arylamino)naphthalenes of interest was successfully developed (**Figure 2**). In the last year, we have successfully scaled-up these reactions and are now able to produce multigram quantities of ligand for use in complexation reactions with Al and Ga.



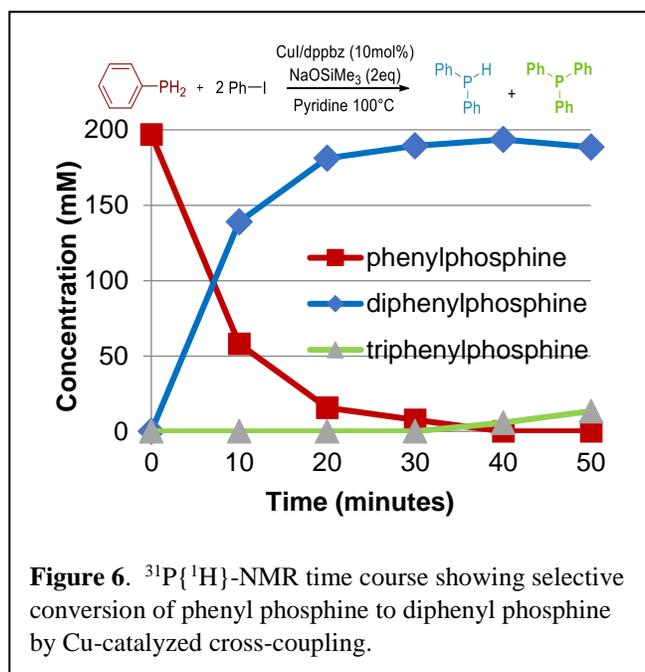
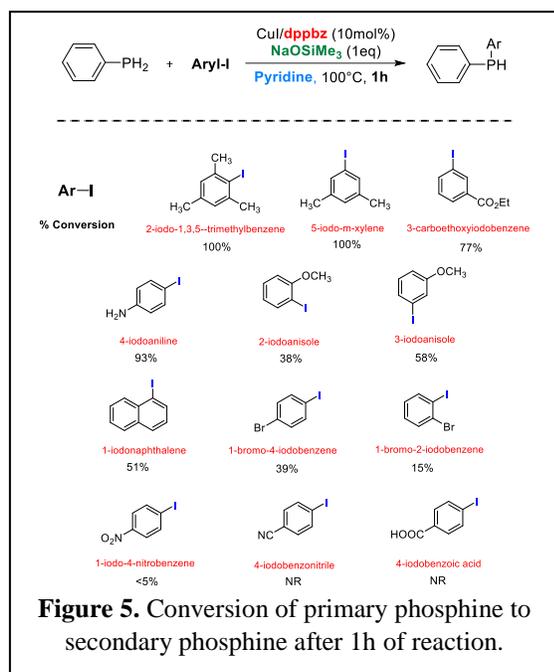
1,8-bis(arylphosphino)naphthalenes: Initial efforts at producing bis(arylphosphino)naphthalene ligands were met with significant challenges. The initial full synthetic plan was based on literature precedent (**Figure 3**). We observed that synthesis by this route was plagued by the formation of diphosphane side products, yielding complex mixtures. Attempts to reduce the diphosphanes with agents such as LiAlH₄ necessitated high temperature vacuum distillations of products and led to very poor yields.

We sought out a cross-coupling method to prepare the desired 1,8-bis(phenylphosphino)naphthalene. Unfortunately, we could not identify a system from the literature that selectively converts primary phosphines to secondary phosphines. Building on the work of Stelzer, who showed that P-C cross-coupling reactions could be in principle be used to make secondary phosphines, we undertook the task of developing a P-C cross-coupling reaction that was selective for secondary phosphine synthesis. At the time of proposal submission,

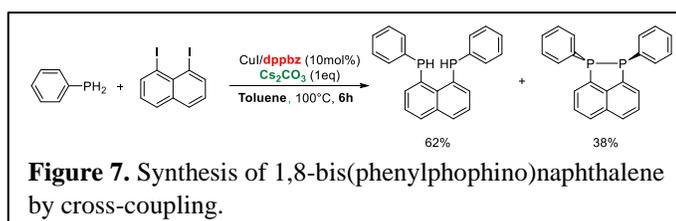


we had developed a preliminary heterogenous P–C cross-coupling system for the production of secondary phosphines (**Figure 4**).

In the last year, further optimization of this system led to a much more efficient homogeneous system using pyridine as solvent and 1,2-bis(diphenylphosphino)benzene (dppbz) supporting ligand as shown in **Figure 5 (top)**. Even with prolonged heating in the presence of excess aryl halide and base, no appreciable tertiary phosphine side product is produced (**Figure 6**). The optimized system shows high conversion for a variety of aryl halides. **Figure 5 (bottom)** shows the one-hour conversion yields under identical conditions for a variety of aryl iodides. The reaction is fastest for electron-rich aryl iodides (e.g. mesityl iodide) and does not work for electron poor aryl iodides (e.g. p-iodobenzonitrile). With the exception of 4-iodobenzoic acid, p-iodonitrobenzene and p-iodobenzonitrile, reactions can be brought to completion with prolonged heating. Products are isolated in moderate to good yields (40-88%) by simple chromatography on silica performed in an inert atmosphere glovebox. These results are currently being written up for publication.



Application of this system to the synthesis of 1,8-bis(phenylphosphine)naphthalene was not straightforward and proceeded to produce large amounts of trans-diphosphane side product. However, reversion to a heterogenous toluene system and manipulation of reaction conditions allowed significant amounts of the desired product to be synthesized and isolated by chromatography (**Figure 7**). Further optimization and scaling-up of this reaction is in progress.



Impact:

The first year of funding has supported research opportunities for 3 undergraduate students. Two students have graduated and been accepted to top medical schools. Travel funds from ACS PRF have allowed a postdoc to present the results on P–C cross-coupling at an ACS National meeting. The PI has also given several talks at ACS local and national meetings about the P–C cross-coupling results. The current results will be used for upcoming submission of both NSF-MRI and NSF RUI proposals.