

seen to be consistent with its being attached to a site of small charge.

Acknowledgment. Support of this work by the NIH (Grant GM 27022) is gratefully acknowledged.

Synthesis of Amines through Nucleophilic Addition on Nitrogen

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Received April 23, 1984

Nucleophilic displacements at carbon are well-known and form the basis of many useful synthetic reactions.¹ However, similar reactions at quaternary nitrogen proceed with difficulty² if at all.³ There are a few reports of nucleophilic attack by alkyl Grignard reagents on trivalent nitrogen compounds including *O*-methylhydroxylamine⁴ and chloramine⁵ (0–90% yields). Addition of nucleophilic reagents to unsaturated nitrogen has also been used as a means of synthesizing amines from organometallic compounds. For example, Grignard reagents react with tosyl azide to form salts of tosyl triazenes which can be reduced to amines.⁶ Reactions of aryl Grignards and aryllithiums with acetone oxime give the corresponding arylamines in yields of 12–70%.⁷ [*p*-Tolylsulfonyl]isonitroso]malononitrile reacts with malononitrile under basic conditions to yield salts of 1,1,3,3-tetracyano-2-azopropenide.⁸ An unusual feature of this reaction is the addition of the nucleophile to the more electronegative atom of the C=X bond, but the usefulness of the method as a general synthetic route to amines is limited. Nucleophilic additions to the hetero atom of C=X bonds have been reported where the hetero atom is nitrogen,^{6–9a,b,c} sulfur,^{10a,b} or oxygen.¹¹ In all cases yields vary from 30% to 80%. Other methodologies for primary arylamine synthesis in useful yields involve the use of methoxyamine and methylithium for the conversion of aromatic organometallics to primary amines. The yields are promising for aryllithiums (55–97%) but low for phenyl Grignard (37%).^{12a,b} The reaction of aromatic organometallics with azidomethyl phenyl sulfide also yields the primary arylamine (50–98%). Present drawbacks of this elegant and valuable approach include the difficulty in preparing the starting material and the unpleasant aroma of phenyl thiol.^{13a,b,c} Primary arylamines have also been obtained in 69–79% yield from the reaction of (trimethylsilyl)methyl azide (TMSMA) with aryl Grignards. Yields are poor for aryllithium reagents (35–41%).¹⁴

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
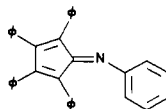
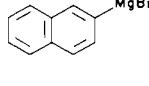
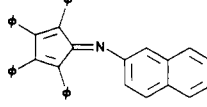
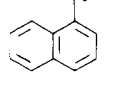
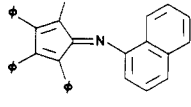
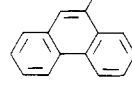
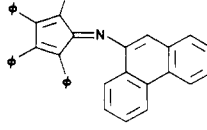
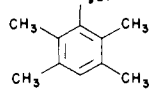
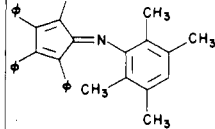
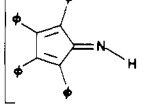

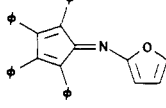

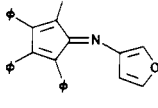
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Table I

organometallic	imine	mp, °C ¹⁸	yield, % ^a
1. 		225–226	95 ^e
2. 		163–165	78 ^{e,f}
3. 		224–225	70 ^{b,e,f}
4. 		202–205	83 ^{e,f}
5. 		174–175	65–68 ^{b,e,f}
		170–173	20 ^{c,e}
6. 		103–105	81 ^{e,f,g}
7. 		178–180	78 ^{e,f,g}
8a. benzanilide			90 ^d
8b. tetraphenylcyclopentadienone oxime			95 ^d

^a Yield of product recovered after liquid chromatography.

^b Identified by elemental analysis. ^c Reduction product of the reaction of (2,3,5,6-tetramethylphenyl)magnesium bromide with the oxime *O*-tosylate. ^d Identified by comparison with authentic sample. ^e Identified via high-resolution mass spectrometry.

^f Yield is not optimized. ^g Yield of recrystallized product. No chromatographic separation.

In the present paper, we report an efficient method for the amination of organometallic reagents. A novel feature of this approach is a "catalytic" cycle in which the amination reagent (hydroxylamine) is activated by oxime tosylate formation (Figure 1).

The starting material of the present work is easy to prepare (Figure 1): tetraphenylcyclopentadienone is synthetically and

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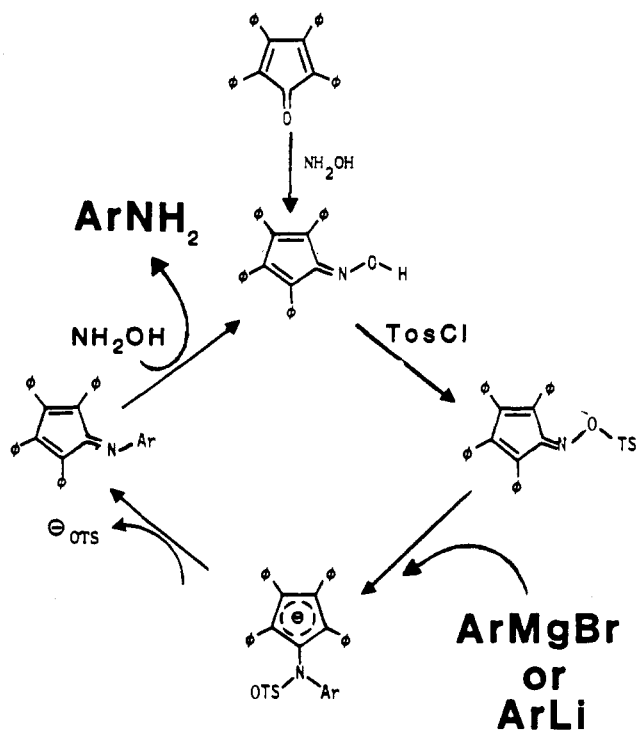


Figure 1.

commercially available; the oxime and oxime *O*-tosylate are readily obtained by successive treatment with hydroxylamine and tosyl chloride.

The reaction leading to the formation of the imine probably proceeds via nucleophilic addition to the heteroatom, creating a highly stabilized cyclopentadienyl anion. The intermediate anion then undergoes elimination of the tosylate. The only significant side reaction appears to be reduction of the imine tosylate to the unsubstituted imine (vide infra). One possible means of eliminating this problem may be substituting a different carbanion stabilizing moiety for the tetraphenylcyclopentadiene system. This type of structural change may also prove to be an effective means for tailoring a specific substrate to match a particular organometallic reagent.

The present results (Table I) demonstrate that the oxime *O*-tosylate of tetraphenylcyclopentadienone reacts with aryllithium or arylmagnesium bromide to give the corresponding imine in good to excellent yield. The final reaction involves the conversion of the imine to the oxime and arylamine and is carried out by reaction with excess hydroxylamine in aqueous pyridine (e.g., entry 8a, Table I). Significant features of this synthetic method are the good yields of aryl amines which are obtained, and the unusual mode of activating the effective aminating reagent *O*-tosylhydroxylamine by attaching an auxiliary group (tetraphenylcyclopentadienyl moiety) which then can be removed and efficiently recycled through the sequence (e.g., Figure 1; entry 8b, Table I).^{19,20}

(19) Aliphatic lithium and Grignard reagents also react with the oxime *O*-tosylate of cyclopentadienone to yield the corresponding imine. Competing side reactions are the formation of the unsubstituted imine and double addition of the nucleophile on nitrogen to yield 1-(dialkylamino)-2,3,4,5-tetraphenylcyclopentadiene, 1-(alkylamino)-2,3,4,5-tetraphenylcyclopentadiene and 1-amino-2,3,4,5-tetraphenylcyclopentadiene. The reaction of *n*-BuZnBr with the oxime tosylate yields comparable amounts of the unsubstituted imine and the *n*-butylimine, but no double addition is observed. This suggests that oxime tosylates may be useful in efficient synthesis of aliphatic amines, if organometallic reagents with metals less electropositive than lithium, magnesium, or zinc are employed and if the oxime moieties are chosen to maximize stabilization of carbanion intermediates (arising from nucleophilic addition on nitrogen) in preference to radical intermediates formed by one-electron transfer. Preliminary experiments with functionalized organolithiums and organomagnesiums (e.g., *N,N*-dialkylcarboxamide, methoxy, α -thio) indicate that optimal yields of monosubstituted imines are highly dependent on the choice of metal, and investigation of this aspect is in progress.

Acknowledgment. This work was supported in part by a grant from the donors of the Petroleum Research Fund, administered by the American Chemical Society, by the Pennwalt Corporation Grant of Research Corporation, by NSF, and by continued assistance from the University Research Committee (UCLA). M.J.T. acknowledges a President's Undergraduate Fellowship. We thank Professor Wayne Thompson, Kenneth Kloc, and Chris Buhr, for stimulating discussions and preprints.

Registry No. *N*-Phenyl-2,3,4,5-tetraphenylcyclopentadienimine, 35160-46-4; *N*-(2-naphthyl)-2,3,4,5-tetraphenylcyclopentadienimine, 91550-18-4; *N*-(1-naphthyl)-2,3,4,5-tetraphenylcyclopentadienimine, 91550-19-5; *N*-(9-phenanthryl)-2,3,4,5-tetraphenylcyclopentadienimine, 91550-20-8; *N*-(2,3,5,6-tetramethylphenyl)-2,3,4,5-tetraphenylcyclopentadienimine, 91550-21-9; 2,3,4,5-tetraphenylcyclopentadienimine, 91550-22-0; *N*-(2-furyl)-2,3,4,5-tetraphenylcyclopentadienimine, 91550-23-1; *N*-(3-furyl)-2,3,4,5-tetraphenylcyclopentadienimine, 91550-24-2; tetraphenylcyclopentadiene oxime tosylate, 91550-25-3; phenylmagnesium bromide, 100-58-3; 2-naphthylmagnesium bromide, 21473-01-8; 1-naphthylmagnesium bromide, 703-55-9; 9-phenanthrylmagnesium bromide, 71112-64-6; 2,3,5,6-tetramethylphenylmagnesium bromide, 75724-98-0; 2-lithiofuran, 2786-02-9; 3-lithiofuran, 53101-93-2; aniline, 62-53-3; tetraphenylcyclopentadiene oxime, 91550-26-4.

Supplementary Material Available: Full experimental details for preparation of oximes and imines (2 pages). Ordering information is given on any current masthead page.

(20) It has been found that the reaction times are much shorter when an excess of organometallic reagent is used, compared to stoichiometric amounts of oxime tosylate and organometallic (10-60 min vs. overnight). For inexpensive organometallics this practice is of little consequence but the experimental conditions reported here may require modification when stoichiometric quantities are employed. Many aromatic amines are considerably more expensive than the corresponding bromides used as precursors for the organometallic reagent (e.g., 9-aminophenanthrene \$108/g vs. 9-bromophenanthrene, \$1/g.; Aldrich catalog, 1984-1985; see Table I, entry 4).

Design and Reactivity of Topologically Unique, Chiral Phosphoramides. Remarkable Diastereofacial Selectivity in Asymmetric Olefination and Alkylation

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Received April 24, 1984

In spite of the phenomenal progress made in the general area of asymmetric synthesis in recent years,^{1,2} comparatively little effort has been devoted to asymmetric olefination reactions and the few examples have involved substituted cycloalkanones.^{3,5} In addition to the many problems that are omnipresent in Wittig-type olefinations,^{6,7} controlling the stereochemistry of unsymmetrical olefins is perhaps a most sought after requirement.^{8,9} In this

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