CHEMCOMM Communication
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A versatile synthesis of planar chiral ligands

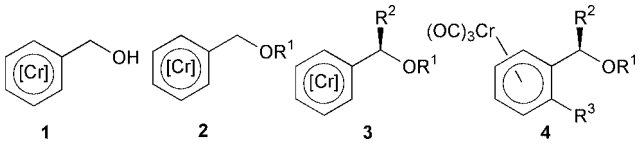
Susan E. Gibson (née Thomas)* and Hasim Ibrahim

Department of Chemistry, King's College London, Strand, London, UK WC2R 2LS. E-mail: susan.gibson@kcl.ac.uk

Received (in Cambridge, UK) 4th April 2001, Accepted 25th April 2001
First published as an Advance Article on the web 22nd May 2001

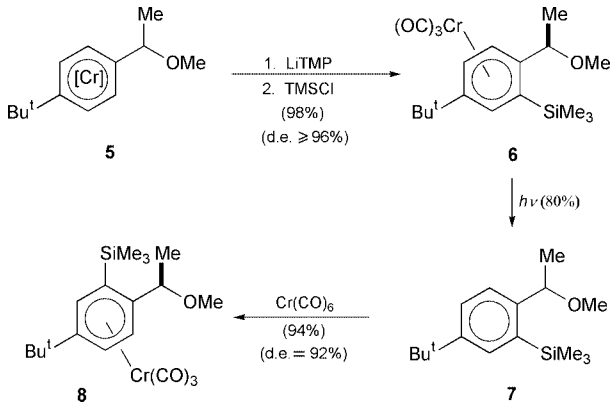
Introduction of a *p*-Bu^t substituent onto tricarbonylchromium(0) complexes of benzyl ethers facilitates clean and selective *ortho* functionalisation; this reactivity is the basis of a key step in a short and versatile synthesis of enantiomerically pure planar chiral complexes.

The potential of non-racemic chiral (arene)tricarbonylchromium(0) complexes as ligands in asymmetric catalysis has been recognised.[1] As a result, an increase in activity in this area in the last three years has led to the successful application of planar chiral (arene)tricarbonylchromium(0) complexes as catalyst ligands in a diverse range of transformations including rhodium-catalysed hydrogenation of ketones,[2] palladium-catalysed aminations of aryl bromides,[3] palladium-catalysed hydrovinylations of styrene,[4] rhodium-catalysed hydroborations of styrene,[5] palladium-catalysed allylic alkylations,[6] iridium-catalysed hydroaminations[7] and Lewis acid-catalysed Diels–Alder reactions.[8] It is acknowledged, however, that although a variety of different synthetic strategies exists for the preparation of planar chiral (arene)tricarbonylchromium(0) complexes, there is still a need for more general approaches that allow the efficient preparation of a greater number of complexes.[1] We recently demonstrated that tricarbonylchromium(0) complexes of benzyl ethers, **2**, which are readily available from (benzyl alcohol)tricarbonylchromium(0) **1** could be asymmetrically functionalised to give complexes **3** in high yield and ee using chiral base methodology.[9] In view of the current interest in planar chirality and the flexibility and efficiency of our route to **3**, we wanted to convert the central chirality of **3** into complexes with planar chirality, represented by **4**. We report herein how we achieved this goal and in doing so provided the foundations of a novel and versatile route to non-racemic planar chiral (arene)tricarbonylchromium(0) complexes.



1 **2** **3** **4**

In contrast to the highly selective deprotonation–electrophilic quench chemistry to tricarbonylchromium(0) complexes of derivatives of α-methylbenzylamine,[10–12] deprotonation and subsequent electrophilic quenching of tricarbonylchromium(0) complexes of benzyl ethers is known to be unselective using the bases Bu^{n}Li,[10] Bu^{s}Li[11] and Bu^{t}Li,[11,12] giving rise to mixtures containing *inter alia* products of ring deprotonation and benzylic deprotonation. Our attempts to deprotonate **3a** (R^1 = R^2 = Me) with LiTMP and quench with chlorotrimethylsilane under a wide range of conditions also gave messy mixtures containing *ortho, meta* and *para* silylated products derived from uncontrolled ring deprotonation. Our attention then turned to the novel complex **5**,† synthesised initially in racemic form by thermolysis of the corresponding benzyl ether with hexacarbonylchromium(0) (97%). It was anticipated that the *p*-Bu^t substituent on **5** would direct deprotonation–electrophilic quench to the desired *ortho* positions of the ether. On reaction with LiTMP followed by a chlorotrimethylsilane quench, we were delighted to isolate the *ortho* silylated product **6** in 98% yield (Scheme 1). The ^{1}H NMR spectrum of **6** indicated that



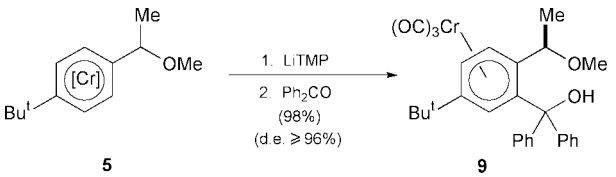
5 **6** **8** **7**

Scheme 1

only one diastereomer had been generated. To confirm that this was the case, the tricarbonylchromium(0) unit was removed from **6** to give **7** which was subsequently heated with hexacarbonylchromium(0) to give a 24:1 mixture of diastereomers **8** and **6**. Re-examination of the ^{1}H NMR spectrum of **6** established the absense of diastereomer **8** and hence the diastereoselectivity for the conversion of **5** to **6** is ≥96%.

In view of the highly selective introduction of a trimethylsilyl group into complex **5**, we decided to investigate the introduction of substituents which would provide useful donor atoms to metals. Deprotonation of **5** with LiTMP followed by addition of benzophenone gave the *ortho*-substituted product **9** in 98% yield (Scheme 2). The relative stereochemistries of the trimethylsilyl isomers **6** and **8** and the hydroxy complex **9** were initially assigned using the model developed for tricarbonylchromium(0) complexes of α-methylbenzylamine derivatives.[10–12] An X-ray crystallographic analysis of **9**[13] revealed that these assignments were correct and that co-ordination of the base to the ether oxygen plays a crucial role in the observed diastereoselectivity. Introduction of a sulfur-containing group was demonstrated on the ethyl ether complex **10**. Reaction of **10** with LiTMP followed by diphenyl disulfide gave complex **11** in 57% yield and ≥96% de (Scheme 3).

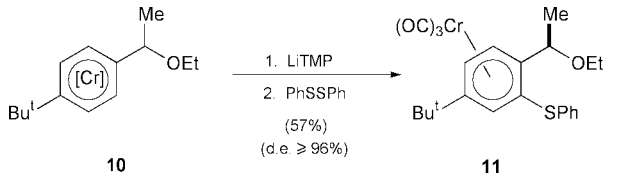
Having demonstrated that *ortho* substituents could be introduced into the *p*-Bu^t substituted complexes **5** and **10** in good yield and with high diastereoselectivity, we turned our attention to synthesising complexes of type **4** in enantiomerically pure form. Complex (4-*tert*-butylbenzyl alcohol)tricarbonylchromium(0), **12** [synthesised in 97% yield from the commercially available alcohol and hexacarbonylchromium(0)] was reacted with acidic methanol to give complex **13** in 97% yield (Scheme 4). (It is of note that the *p*-Bu^t substituent not



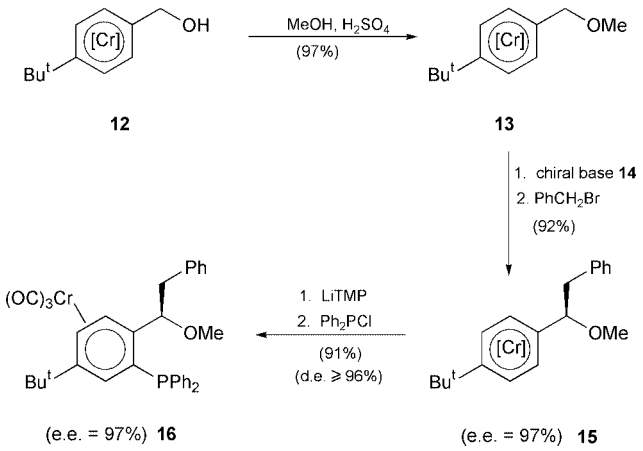
5 **9**

Scheme 2

 DOI: 10.1039/b103058m

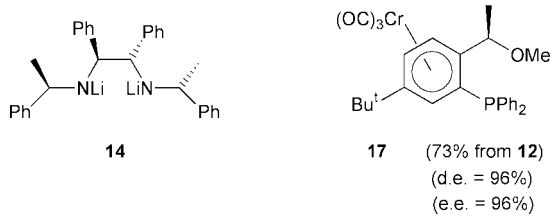


Scheme 3



Scheme 4

only gives rise to the excellent selectivity described herein, but it also confers a high degree of stability and crystallinity on its (arene)tricarbonylchromium(0) complexes.) Subsequent treatment of **13** with chiral base **14** followed by benzyl bromide gave complex **15** in 92% yield and 97% ee (as determined by chiral



HPLC analysis). The absolute stereochemistry of **15** was assigned as *R* based on results obtained in our previous studies using chiral base **14** and benzyl ether complexes lacking the *p*-Bu^t substitutent.[9] Finally deprotonation of **15** with LiTMP followed by addition of Ph_2PCl gave complex **16** in 91% yield, ⩾96% de and 97% ee. A similar three-step sequence created complex **17** in 96% ee and ⩾96% de in 73% overall yield from complex **12**.

In conclusion, we have demonstrated that the introduction of a *p*-Bu^t substituent onto tricarbonylchromium(0) complexes of benzyl ethers enables them to be cleanly and selectively functionalised at the *ortho*-position for the first time. This new mode of reactivity has enabled us to convert readily-available (4-*tert*-butylbenzyl alcohol)tricarbonylchromium(0), **12**, into enantiomerically pure planar chiral complexes **16** and **17** in three steps. As each step involves the introduction of a new substituent, this sequence constitutes a very versatile synthesis of planar chiral complexes, many of which have potential as ligands in asymmetric synthesis.

The authors thank King's College London for a studentship (H. I.).

Notes and references

† The novel compounds **5**–**13** and **15**–**17** all gave satisfactory spectroscopic (IR, ^{1}H NMR, ^{13}C NMR, ^{31}P NMR and low resolution MS) and microanalytical data.

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