Reverse Halogenation Using Supported Copper(I) Iodide

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Alumina and charcoal supported copper(I) iodide reagents can be used to convert bromo- and chloro-benzenes into iodobenzenes with no back attack by bromide or chloride.

In normal copper(I) promoted reactions the ease of displacement of a halogen follows the order I > Br > Cl whereas the ease of introduction of a halogen follows the reverse order. For these reasons, CuI is a popular choice for many copper(I) promoted reactions because of the reduced possibility of the iodide anion interfering with the desired reaction.[1] Aryl iodides, the only aryl halide that cannot be obtained by direct halogenation, cannot normally be prepared by copper(I) Finkelstein-type halide exchanges between aryl bromide (or chloride) with copper(I) iodide. It has been reported that reactions of this type can be promoted by certain types of nickel systems but these either require large excesses of I^- so as to achieve reasonable conversions[2] or they result in substantial amounts of biaryls as byproducts.[3]

We have recently described the first examples of reactive solid forms of a copper(I) reagent, alumina–CuCN and charcoal–CuCN which are believed to contain both Cu^+ and $Cu(CN)_2^-$ ions dispersed on the surfaces of the supports.[4] The major advantages of these interesting materials is that they are reactive towards aromatic substrates in non-polar solvents. We now report the successful preparation of supported copper(I) iodide which not only maintains this advantage but more significantly, can be used for the efficient conversion of bromobenzenes (and less successfully, chlorobenzenes) to iodobenzenes.

The supported reagents alumina–CuI and charcoal–CuI were prepared *via* $KCuI_2$. A freshly filtered solution of CuI in aqueous KI was stirred rapidly with the required amount of the support. Water was added to this stirred mixture over a period of several hours so as to slowly precipitate the CuI on to the support. The materials were then washed several times with water, ethanol, and ethoxyethane before being dried under vacuum at room temperature. Reaction of alumina–CuI (1 mmol g^{-1} of support) or charcoal–CuI (3.3 mmol g^{-1} of

Table 1. Results of the exchange reactions between aryl bromides and chlorides and CuI.

Reagent	Substrate	Solvent	Time/h	Aryl iodide/%[b]
Alumina–CuI[a]	Bromobenzene	—	27	94
Charcoal–CuI	Bromobenzene	—	28	92
Alumina–CuI	Bromobenzene	t-Butyl benzene	40	25
CuI	Bromobenzene	—	36	0
CuI	Bromobenzene	NMP	30	2
Alumina–CuI	Chlorobenzene	—	60	58
Charcoal–CuI	Chlorobenzene	—	60	60
Charcoal–CuI	2-Bromotoluene	—	23	86
Charcoal–CuI	4-Bromotoluene	—	36	90
Alumina–CuI	2-Bromotoluene	—	48	40
Alumina–CuI	4-Bromotoluene	—	23	42

[a] Reactions were carried out with vigorous stirring at 150 °C except for the reactions of chlorobenzene which were carried out at 130 °C. [b] Reactions were monitored by g.c. and yields quoted are g.c. conversions. Products were confirmed by g.c.–mass spectrometry.

support) with bulk bromobenzene at 150 °C in a well stirred system gave 90% iodobenzene based on the amount of CuI used (Table 1). There was no observed reduction in this product yield after extended periods of time. Iodination of bromobenzene could also be achieved using t-butylbenzene as the bulk solvent although reactions were slower. CuI itself gave no detectable reaction with bulk bromobenzene and only traces of iodination resulted when the reaction was carried out in *N*-methylpyrrolidine (NMP) (a 'favoured' solvent for Cu^I promoted reactions[1]).

In an attempt to discover if the observed reactions were reversible, the recovered support containing solid CuBr was treated with bulk iodobenzene. No bromination was observed, strongly suggesting that the CuBr produced in the original reactions was in an inactive form. It seems likely that the reactivity of the original CuI material is due to the presence of Cu^+ and CuI_2^- species dispersed and stabilised on the support surface [*cf.* Cu^+ $Cu(CN)_2^-$ suggested for supported CuCN][4]. Presumably, the CuBr produced in the reaction systems is either not well dispersed on the support or, more likely it exists on the support surface in a form such as simple monomeric CuBr which is not itself reactive towards aromatic substrates. The importance of the method of Cu^I salt loading on to the support is clear.

We were able to use our supported CuI materials to convert chlorobenzene into iodobenzene (a much more difficult exchange) although the reactions were slow, giving *ca.* 1% iodination per hour at the somewhat lower reaction temperature of 130 °C. We have also attempted the iodination of 2- and 4-methyl bromobenzenes to see if an *ortho* substituent causes the rate acceleration often observed in Cu^I promoted reactions.[1] Interestingly, while 2-bromotoluene was iodinated at a faster rate than 4-bromotoluene using charcoal–CuI, the opposite was true for alumina–CuI. Indeed the reactivity of 2-bromotoluene with alumina–CuI is appreciably less than that of bromobenzene itself suggesting that the *ortho* substituent has an overall negative effect on reactivity. It is possible that the additional bulkiness of the 2-methyl group creates problems with pore accessibility. A large proportion of the surface area of alumina is located within micro- and mesopores so that the size of the incoming substrate is of vital importance. The highly particulate charcoal however, possesses an extremely high external surface area. We can again make a useful comparison with supported CuCN materials; alumina–CuCN is effective for the cyanation of bromobenzene but not bromobiphenyl.

Our new materials represent the first class of Cu^I reagents that can be used for selective aryl iodinations. Their reactivity can be attributed to good surface dispersion of reactive copper species, probably Cu^+ and CuI_2^-, and the formation of unreactive CuBr or CuCl during iodination reactions which prevents equilibration in favour of the less reactive bromo- or chlorobenzenes. Our preliminary results suggest that alumina–CuI may show substrate isomer selectivity that is controlled by substrate bulkiness rather than normal Cu^I chelation effects. Our materials represent a further breakthrough in the development of new and useful supported reagents for the synthetic chemist.

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References

1 J. Lindley, *Tetrahedron*, 1984, **163**, 1433.

2 S. H. Young, C. S. Li, and C. H. Cheng, *J. Org. Chem.*, 1987, **52**, 691.

3 K. Takagi, N. Hayama, and T. Okamoto, *Chem. Lett.*, 1978, 191.

4 J. H. Clark, C. V. A. Duke, S. J. Brown, and J. A. Miller, *J. Chem. Soc., Chem. Commun.*, 1986, 877.