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LIGAND MIXING IN LOWER ORDER ORGANOCUPRATES: SYNTHETIC, MECHANISTIC, AND STRUCTURAL IMPLICATIONS+

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SUMMARY: *NMR spectroscopic evidence attesting to facile ligand exchange between lower order cuprates in THF and* Et_2O *solution is discussed. A mechanistic pathway is suggested to account for ligand redistribution in THF. A dimeric model for* R_2CuLi *is supported by the spectral data.*

The utility of mixed organocuprate reagents, of both the higher[2] and lower order (LO)[3] variety, for purposes of conserving valuable transferable ligands is now well established. Whether these reagents exist as represented in 1, or as components of an equilibrium with homocuprates 2 and 3 is at issue.[4] Earlier work from our laboratories, employing both chemical and spectroscopic methods, had shown (for the cases studied in THF) that an

$$R_TLi + R_RLi + CuI \longrightarrow \underset{\underset{\sim}{1}}{R_TR_RCuLi} \rightleftharpoons \underset{\underset{\sim}{2}}{R_{T_2}CuLi} + \underset{\underset{\sim}{3}}{R_{R_2}CuLi} \quad \ldots(1)$$

equilibrium such as that described in equation (1) lies far toward the side of 1.[5] Thus, the admixture of Me_2CuLi with R_2CuLi (R = n-Bu or t-Bu) leads to a new proton spectrum superimposable with that observed from sequential addition of MeLi and either n-BuLi or t-BuLi to CuI, both presumably affording R(Me)CuLi. It was also found that treatment of Me_2CuLi (in THF) with 1 equiv of n-BuLi leads to the same spectrum seen above, with R=n-Bu, plus a new singlet characteristic of free MeLi. This indicates that an n-Bu ligand can readily replace a methyl group in Me_2CuLi, suggesting that ligand exchange between copper centers in THF is quite a facile process.

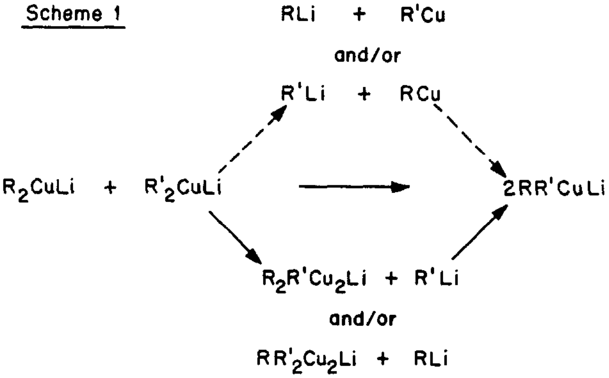
+Dedicated with warmest congratulations, on the occasion of his 65th birthday, to Professor Harry H. Wasserman; former mentor,... and a good friend.

Our recent studies on Gilman's reagent (i.e., "Me_2CuLi") in THF using ^7Li NMR, and in the absence of LiI, have documented an unexpected and unprecedented equilibrium, as shown in eq. (2).[6] On the basis of these findings we can now propose a mechanism consistent with the chemical and spectral data[6] which accounts for ligand mixing of LO organocuprates (Scheme 1).

$$Me_3Cu_2Li + MeLi \rightleftharpoons [Me_2CuLi]_2 \qquad \ldots(2)$$

In THF, Me_3Cu_2Li (i.e., MeCu + 0.5 MeLi, and therefore, presumably R_3Cu_2Li in general)[7] represents the complex derived from the minimum amount of MeLi (RLi) necessary to solubilize CuI, and is thus the fundamental species in solution.[8] Realization that both Me_3Cu_2Li and MeLi are present in solutions of Me_2CuLi provides a pathway by which free RLi(R'Li) may recombine to form RR'CuLi (Scheme 1). The percentage of each resulting cuprate (i. e., R_2CuLi, R'_2CuLi, RR'CuLi) should reflect the thermodynamics of the equilibria involved, varying as a function of the similarities/differences (e.g., in basicities, size, etc.) between the RLi/R'Li in solution.

Scheme 1

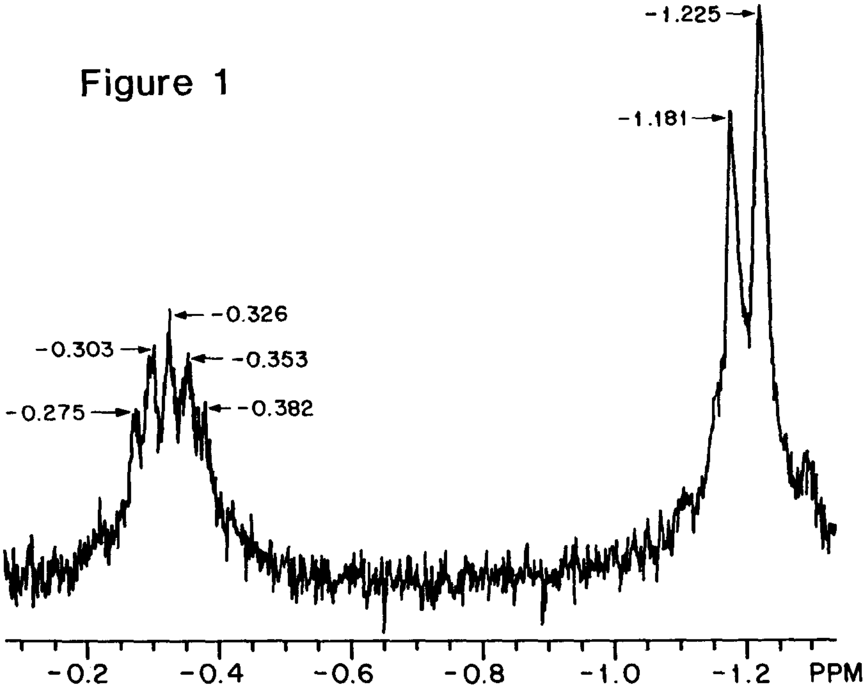


In Et_2O, the situation is quite different: R_3Cu_2Li is insoluble, and $R_5Cu_3Li_2$ (i.e., 0.66 MeLi:MeCu) becomes the primary cuprate in this medium.[8] The ^1H and ^7Li NMR spectra for Me_2CuLi in Et_2O (without LiI) do not, however, reveal the presence of free MeLi.[6] Thus, should an equilibrium related to that in THF be present [equation (2)], it would seem to lie heavily toward Me_2CuLi (equation 3).[9]

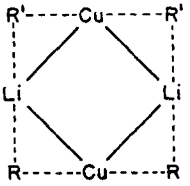
$$2\ Me_5Cu_3Li_2 + 2\ MeLi \longrightarrow 3\ (Me_2CuLi)_2 \qquad \ldots(3)$$

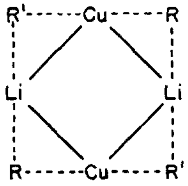
The apparent lack of free RLi would suggest that mixing experiments, similar to those conducted in THF between different cuprates, would not result in rapid ligand exchange. In the event, addition of Me_2CuLi (in Et_2O) to $\underline{n}$-Bu_2CuLi/Et_2O gives a ^1H NMR spectrum (Figure 1) which is identical to that obtained upon combining MeLi + $\underline{n}$-BuLi + CuI in Et_2O (1:1:1 ratio).[11] Introduction of 1 equiv of $\underline{n}$-BuLi to Me_2CuLi in Et_2O leads to the same spectrum, plus free MeLi. Thus, irrespective of the possible mechanistic avenues, some of which may go spectroscopically undetected,[12] it is clear that ligand redistribution occurs in both THF and Et_2O solutions.

Figure 1



Still more curious, given that exchange between cuprates does take place in Et_2O by some as yet unestablished mechanism, is that two new sets of signals appear for n-Bu(Me)CuLi in the ^1H NMR spectrum. The data can be explained by assuming a dimeric state[7,13] for n-Bu(Me)CuLi, where the possibility exists for both *cis* and *trans* isomers to be present, as shown below. While this hypothesis also assumes a limited affect on structure by LiI, which is contrary to Power's X-ray data on the Ph_2CuLi related anion $[Cu_3Li_2Ph_6]^-$ (represented as $[(Ph_2CuLi)_3(LiX)])$,[14] it is consistent with both the Pearson[13] and van Koten models.[15]





In summary, given the clear-cut dependence of cuprate make-up on solvent(s) in both lower and higher order systems, it is reasonable that mechanistically unique pathways may exist for ligand exchange between Gilman cuprates in THF vs. Et_2O. The available data suggest that mixed cuprates, commonly used in synthesis, may at least be the predominant and possibly sole species in solution. Finally, these observations support, although by no means prove, a dimeric state of aggregation for mixed LO cuprates.

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References and Notes

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9. It is interesting to note that House, et. al,[10] some 10 years ago suggested that an equilibrium as shown in equation (2) in Et_2O , rather than THF, might exist to account for alcohol products resulting from reactions of saturated ketones with small amounts of free MeLi.
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11. The spectrum in Et_2O is identical to that obtained in THF, aside from changes in chemical shifts, most likely due to solvent effects. The downfield multiplet corresponds to the $CH_3CH_2CH_2\underline{CH_2}$-Cu- protons which give overlapping triplets, while the upfield singlets are assigned to the CH_3 group for the two apparent forms of *n*-Bu(Me)CuLi.
12. For examples: (1) trace amounts (<2%) of $R_5Cu_3Li_2$ and RLi [see equation (3)] may be present; (2) transient higher states of aggregation may exist which permit intra-aggregate ligand exchange; (3) minute quantities of RCu, formed along with RLi and R_2CuLi from $R_4Cu_2Li_2$, recombine with R'_2CuLi (i.e., $RCu + R'_2CuLi \rightleftharpoons RR'_2Cu_2Li \rightleftharpoons R'Cu + RR'CuLi$).
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