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STRUCTURE OF BUTYLLITHIUM-PYRIDINE ADDUCTS

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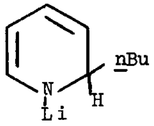
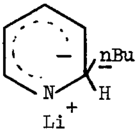
In 1930 Ziegler and Zeiser reported that butyllithium adds to pyridine with subsequent elimination of lithium hydride[1,2] to give 2-butylpyridine. They envisaged the reaction to proceed via I. Subsequently several reactions of this general type between aromatic heterocyclic compounds and organometallic reagents of lithium,[3-9] magnesium,[10-12] and potassium,[2] were reported. Throughout the large volume of these and more recent studies[13,14,15] it has always been assumed that the intermediates are of structure II. The mechanistic conclusions depend on the validity of II, however so far no studies have been reported on the initial adducts themselves.[8,9]



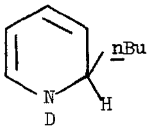
I



II

We now report conclusive evidence, based on n.m.r. data, for the structure of the butyllithium-pyridine adducts.

Butyllithium reacts with a variety of aromatic heterocyclic compounds under mild conditions to give stable adducts. For instance, equimolar quantities of butyllithium and pyridine, mixed at -78° in diethyl ether and warmed to 0°, within an hour yield a deep red solution, this was stable for several hours at room temperature or a week at -78°.* The n.m.r. spectrum of this solution, Figure 1a, reveals that 80% of the pyridine has been converted to a new species. Careful hydrolysis with degassed D_2O at 0° gave at least 95% conversion to the 1-deutero-2-hydro-2-butylpyridine,* III, not isolated.



III

Species II and III were readily identified by their n.m.r. spectra, Figure 1. The ring hydrogens in II and III are shielded by 2-3 ppm with respect to those in pyridine, indicating reduced species. The spectra were analyzed with computer programs NMRIT and NMREN[16] and the results are listed in Table 1. It is seen that the n.m.r. parameters for II and III are very similar. They bear some resemblance to those reported by Saunders for 1-methyl-2-phenyl-1,2-dihydropyridine.[17]

It is instructive to compare the vinyl proton shift in 1,3-cyclohexadiene with those in II and III (Table 1). The chemical shift of the olefinic hydrogens in 1,3-cyclohexadiene is about 4.15τ. Thus the effect of the heteroatom in II and III is to shield the protons at C_3 and C_5 with respect to cyclohexadiene, leaving those at C_4 and C_6 relatively unchanged. The extra shielding at H_3 and H_5 is most likely due to increased π-electron densities at these positions.[18] Therefore the extent of π-electron delocalization in I and III is about the same, the extra π-density at positions 3 and 5 being 0.1 electrons. The structure of the pyridine-butyllithium adduct is best represented by I with the provision that 20% of the negative charge is located at positions 3 and 5, the rest being associated with nitrogen or the N-Li bond.**,***

Results similar to those described above have been found for the adducts of butyllithium with 4-_tert_-butylpyridine (IV), 2-_tert_-butylpyridine (V), and 3-picoline (VI). These adducts are assigned the following structures.

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* Both the butyllithium adduct and the corresponding dihydropyridine undergo conversion to 2-butylpyridine; the adduct slowly with oxygen or heating and the dihydropyridine rapidly at 0°.

** With these experiments it is not possible to determine the location of lithium in II or to learn about the ionic character of the N-Li bond.

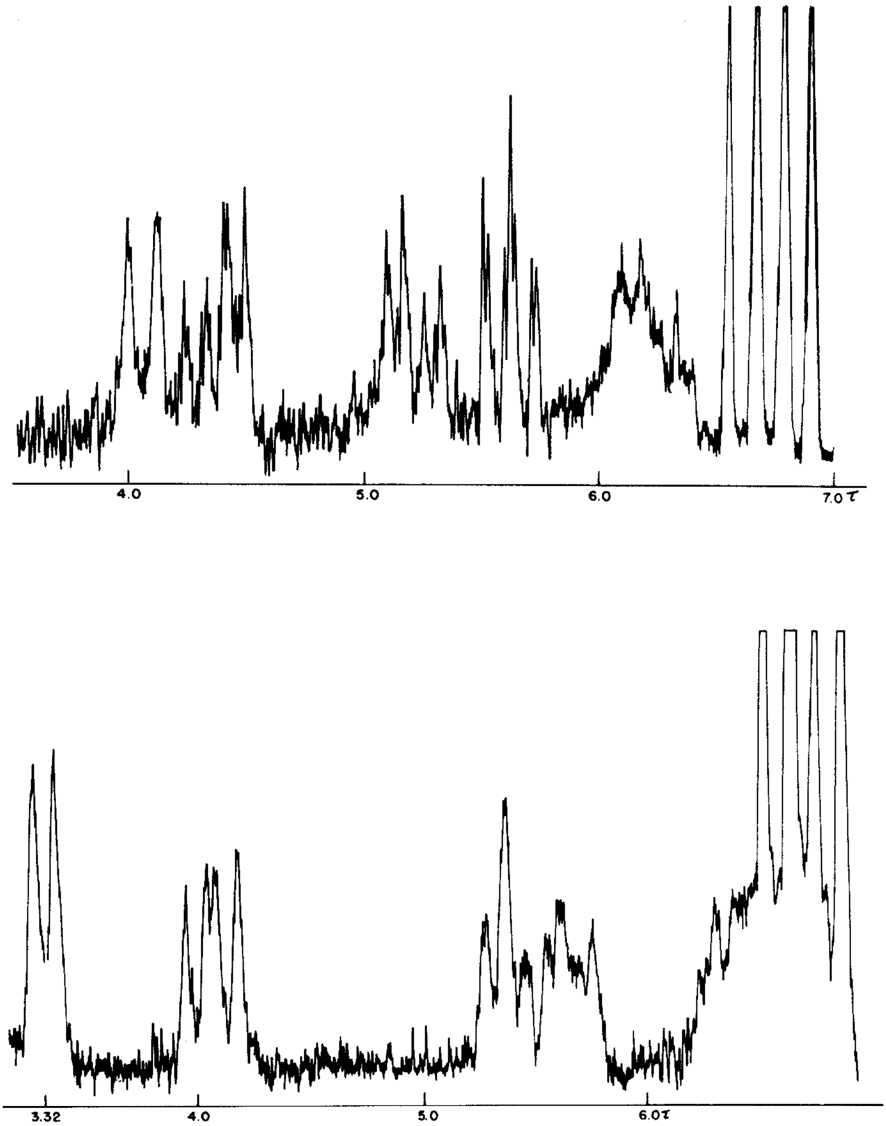
*** A similar π-electron density distribution was obtained from an omega-LCAOMO treatment for the dihydropyridine, III.

TABLE I

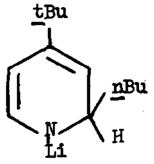
Nmr Parameters for Butyllithium-pyridine adducts,
RHLi, and dihydropyridines RHD

	Pyridine		4-t-butyl pyridine		6-t-butyl pyridine		3-methyl-pyridine
	RHLi	RHD	RHLi	RHD	RHLi	RHD	RHLi
Shifts τ units							
H_2	6.36	6.16	a	a	a	a	a
H_3	5.66	5.23	5.89	6.13	5.68	5.14	-
H_4	4.07	4.39	--	--	4.04	4.32	4.27
H_5	5.38	5.65	5.28	5.38	4.91	5.46	5.44
H_6	3.32	4.06	3.48	3.99	--	--	3.38
Coupling Constants in Hz							
J_{23}	4.19	4.19	3.2	a	a	4.7	-
J_{24}	0.46	1.08	-	-	a	1	a
J_{34}	8.17	9.80	-	-	8.3	9.3	-
J_{35}	0.84	1.27	2.0	a	a	1	-
J_{36}	0	0.89	a	a	-	-	-
J_{45}	5.43	5.40	-	-	5.9	6.0	6.5
J_{46}	0	1.39	-	-	-	-	2.5
J_{56}	5.83	7.11	6.0	8.3	-	-	6.0

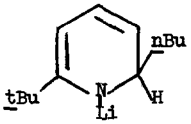
a) Line too broad to assign n.m.r. parameter.



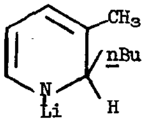
Nmr Spectra: Top, butyllithium-pyridine adduct, 1 M in ether; Bottom, result of hydrolysing above solution with D_2O.



IV



V



VI

In all these experiments we find the butyllithium-pyridine adducts and dihydropyridines to have very similar structures. Butyllithium adducts are written as the localized structures, I, since dihydropyridines are written in this way also.

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