Tetrahedron Letters No. 4, pp 281 - 284, 1972. Pergamon Press. Printed in Great Britain.

CIDNP EVIDENCE FOR A RADICAL PATHWAY IN THE FORMATION OF GRIGNARD REAGENTS

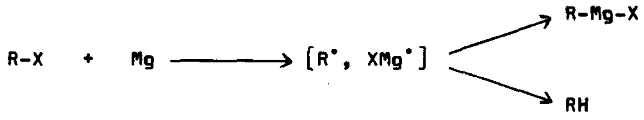
H.W.H.J. Bodewitz, C. Blomberg and F. Bickelhaupt

Chemistry Department, Vrije Universiteit

De Lairessestraat 174, Amsterdam, The Netherlands

(Received in UK 6 December 1971; accepted for publication 23 December 1971)

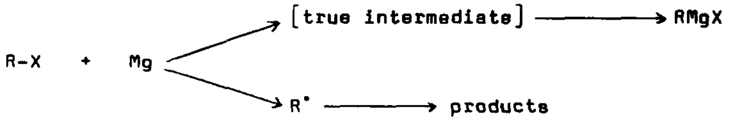
In spite of the tremendous synthetic importance of the Grignard reaction, i.e. the formation of organomagnesiumhalides from organic halides and magnesium, the details of its mechanism are still insufficiently understood. There is some evidence that the intriguing "insertion" of a magnesium atom into the carbon halogen bond occurs stepwise, and that radicals are involved in these steps:



(1)

The presence of an alkyl radical is indicated by the occurrence of the hydrocarbon RH derived from the alkyl halide, sometimes in rather high yields[1,2]. The most plausible explanation is that the intermediate radical R• strips a hydrogen atom from either the solvent or from other molecules RX present on the surface of the metal[3]. Other radical products[4] and stereochemical investigations[1] support this interpretation.

However, none of these results forms compelling evidence for the occurrence of the radical as an intermediate on the direct pathway to RMgX because it cannot be excluded that the radicals are formed in non-Grignard side reactions:



(2)

In this communication we present direct evidence via CIDNP phenomena[5] that radicals are true intermediates in the formation of ethylmagnesium and iso-butylmagnesium bromide in

THF and of ethylmagnesium iodide in di-n-butyl ether.

To about 0.5 ml of the solvent and one mg-atom magnesium crystals (Specpure® magnesium from Johnson Matthey, Chemicals Ltd. London) in an nmr tube a slight excess of an alkyl halide was added and the probe was inserted into the cavity of a Varian A-60 nmr spectrometer. After a few seconds the "multiplet effect" was observed for the protons α to the carbon magnesium bond, which are easily observed due to their characteristic chemical shift around or to higher field from TMS.

Figures 1a and 1b show that at first emission (and probably also enhanced absorption) occurs for the α-protons; within two minutes the normal spectrum is observed. The spectrum of ethylmagnesium bromide in THF was analogous to that of ethylmagnesium iodide in di-n-butyl ether (figure 1a). The reproducibility of the spectra caused some difficulty presumably because of variations in the rate of the reactions even for the same organic halide in the same solvent.

There is also some indication for the CIDNP phenomenon in the β-proton signals of ethylmagnesium bromide in THF; however in this case overlap with the signals of the solvent protons makes interpretation difficult in this system.

That the signals do not originate from a metal-halogen exchange reaction[6,7]:

$$\text{R-Mg-X} + \text{R-X} \rightleftharpoons \text{R-X} + \text{R-Mg-X} \qquad (3)$$

was proved by adding more alkyl halide to the corresponding Grignard solution: no emission or other changes in the α-proton signals were observed.

From these preliminary observations two conclusions can be drawn. First, the occurrence of the CIDNP phenomenon in the Grignard reagent proves unequivocally that this species is formed in a radical process. Furthermore, according to the radical pair model[8], the Grignard reagent must be formed by combination of two radicals; whereas the alkyl radical is an obvious candidate for one of these, the identification of the other radical species (possibly $^{\bullet}$MgX) needs more detailed investigations which are in progress.

For the reactions which we have studied so far we may state that the radical pathway (scheme [1]) is an important, if not the only route to Grignard reagents. Work is now in progress to define more closely the range of validity of this statement and the details of the mechanistic picture.

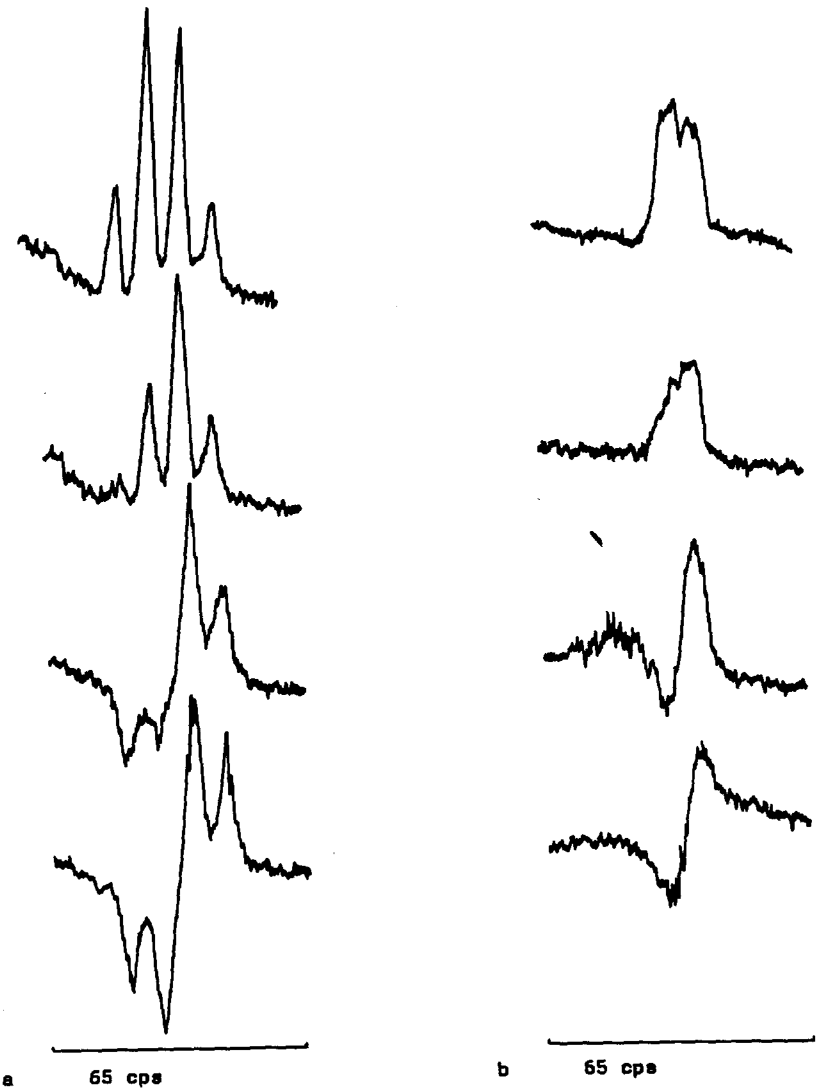


Fig. 1 : 60Mc nmr spectra taken at 0.5 min. intervals of

a) the CH_2-protons of ethylmagnesium iodide in di-n-butyl ether,

b) the CH_2-protons of iso-butylmagnesium bromide in THF.

Acknowledgement

Financial support from the Netherlands Organization for the Advancement of Pure Research (Z.W.O.) via the Foundation for Chemical Research in the Netherlands (S.O.N.) is gratefully acknowledged.

References

1. H.M. Walborsky and A.E. Young, J. Amer. Chem. Soc. 86, 3288 (1964).
2. Cl. Agami, M. Chauvin and J. Levisalles, Bull. Soc. Chim. France, 1970, 2712.
3. Private communication from Prof. Walborsky, whom we thank for reports prior to publication.
4. H.H. Grootveld, C. Blomberg and F. Bickelhaupt, Tetrahedron Letters, 1970, 1999.
5. Proceedings of the CIDNP International Colloquium, Brussels, 18 and 19 March, 1971 in: Industrie Chimique Belge-Science, in press.
6. L.I. Zakharkin, O.Yu. Okhlobystin and K.A. Bilevich, J. Organometal. Chem. 2, 309 (1964).
7. No emission spectra were observed for the metal-halogen exchange reaction in which organolithium compounds were involved: A.R. Lepley, Chem. Commun. 1969, 64.
8. G.L. Closs, J. Amer. Chem. Soc. 91, 4552 (1969);
   R. Kaptein and L.J. Oosterhoff, Chem. Phys. Letters 4, 214 (1969).