Journal of Organometallic Chemistry
Elsevier Sequoia S.A., Lausanne
Printed in The Netherlands

DETERMINATION OF GRIGNARD AND ALKYLMETAL SOLUTIONS BY NMR SPECTROSCOPY

R. JONES

Imperial Chemical Industries Limited, Petrochemical and Polymer Laboratory, The Heath, Runcorn, Cheshire (Great Britain)

(Received April 9th, 1969)

SUMMARY

A satisfactory and convenient NMR method for the estimation of Grignard and alkylmetal solutions is described. The accuracy of the method, which is limited to that given by the NMR integration process, compares favourably with titration techniques.

INTRODUCTION

A recent article[1] mentioning the use of NMR for analysing solutions of butyllithium prompts us to describe a general NMR method which we have developed for estimating Grignard and alkylmetal solutions. The shortcomings of previously described methods are amply discussed by Urwin and Reed[1], and are not recounted here. This paper describes the method, gives results for series of Grignard and alkylmetal reagents, and discusses the procedure generally.

EXPERIMENTAL

Grignard[2] and alkyllithium solutions[3] were prepared by standard procedures in a suitable solvent (usually anhydrous ether, tetrahydrofuran or hexane), and stored under nitrogen in flasks fitted with serum caps. Dimethylmercury was prepared[4] from methylmagnesium bromide and mercuric chloride in ether, and purified by distillation (yield 33%, b.p. 88–89°). A standard solution of this compound was made by dissolving 0.850 g in ether and diluting to 10 ml.

Transfer of known volumes (usually 1 ml) of the organometallic solution to an NMR tube with the exclusion of air and moisture can readily be effected by using the apparatus shown in Fig. 1. The apparatus with NMR tube installed is dried, evacuated, and filled with nitrogen. An accurately measured volume of the solution under investigation is syringed into the NMR tube via the serum cap, followed by a suitable volume of a convenient reference liquid (see Discussion). By maintaining a rapid flow of nitrogen through the apparatus when the serum cap is removed, the NMR tube can quickly be fitted with its cap such that the atmosphere is virtually excluded. Triplicate samples of each solution are prepared, the NMR spectrum of each is taken, and the requisite peaks integrated four times. Comparison of the reference peak intensity with convenient absorption due to the organometallic compound allows calculation of the solutions' concentration with respect to Grignard or alkylmetal reagent.

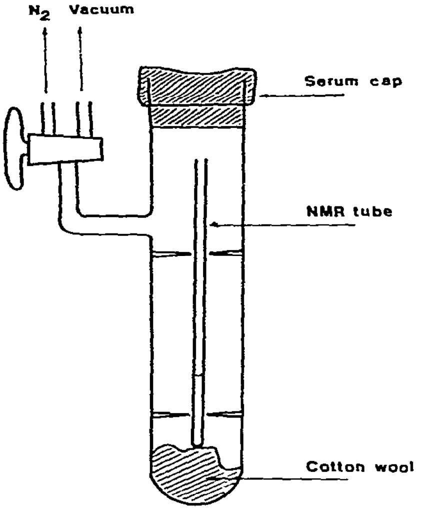

Fig. 1.

Titrometric estimations of the solutions were made by adding excess 0.1 *N* hydrochloric acid solution, and back-titrating the excess with 0.1 *N* sodium hydroxide solution[5]. In the case of butyllithium, the double titration method of Gilman and Haubein was used[6].

RESULTS AND DISCUSSION

Two conditions must be fulfilled to obtain NMR spectra that can be satisfactorily integrated; firstly, the organometallic compound must contain a proton or group of protons which give characteristic absorption at a frequency where the solvent does not interfere; secondly, the reference compound must be liquid, inert, and have absorption (preferably a singlet) which coincides with neither the solvent nor the organometallic compound. In practice these conditions are easily met. In most cases benzene is suitable as a reference, and in those cases when aromatic peaks for the sample are being used, methylene chloride is satisfactory. The volume of reference liquid is chosen to give a peak intensity similar to the signal of the organometallic compound. This was normally 20 or 50 μl which could be delivered with sufficient accuracy from a microlitre syringe.

The wide range of compounds successfully analysed is shown in Table 1 which lists the relevant solvent and reference, together with analysis results obtained from both the NMR and titration determinations. Protons α to magnesium*, lithium, or

---

* No coupling between α protons and ^{25}Mg nuclei (relative abundance 10%, $I=\frac{5}{2}$) has been observed[7] and it is assumed that this is either very small or absent.

TABLE 1

NMR AND VOLUMETRIC DETERMINATIONS OF GRIGNARD AND ALKYLMETAL SOLUTIONS

Compound[a]	Solvent	Reference	Molarity by NMR	Molarity by tritration[b]
$^{*}CH_3MgBr$	Ether	Benzene	1.07 1.15 1.08	0.995
$CH_2{=}\overset{*}{C}HCH_2MgCl$	Ether	Benzene	0.27 0.27 0.30	0.27
$\overset{*}{Ph}CH_2MgCl$	Ether	Methylene chloride	0.89 0.91 0.88	0.87
$p\text{-}CH_3\overset{*}{C}_6H_4CH_2MgCl$	Ether	Methylene chloride	0.46 0.48 0.48	0.47
$p\text{-}CH_3O\overset{*}{C}_6H_4CH_2MgCl$	Ether	Methylene chloride	0.31 0.29 0.30	0.29
$\overset{*}{C}H_3Hg\overset{*}{C}H_3$	Ether		0.42 0.42 0.43	0.425[c]
$\overset{*}{C}H_3Li$	Ether	Benzene	0.40 0.37 0.40	0.38
$CH_3\overset{*}{C}H_2Li$	Hexane	Benzene	0.27 0.275 0.27	0.26
$CH_3CH_2CH_2\overset{*}{C}H_2Li$	Hexane	Benzene	0.67 0.68 0.65	0.64

[a] Signals from protons attached to C atoms marked * are integrated. [b] Average of three titres. [c] Actual concentration as prepared.

mercury in the aliphatic series absorb at sufficiently high field to prevent solvent interference. Methyllithium, methylmagnesium bromide, and dimethylmercury give singlets at δ +1.78, +1.59, and −0.27 ppm*, respectively (*cf.* refs. 8–10).

In the case of dimethylmercury, spin coupling between the methyl protons and ^{199}Hg nuclei (relative abundance 16.9%, $I = \frac{1}{2}$) is evident as a doublet (J = 101 Hz, in agreement with previous work)[10]. No coupling with ^{201}Hg nuclei (relative abundance 13.2%, $I = 3/2$) is seen. For the NMR determination of this compound, either there must be integration over the whole signal (which is impossible), or allowance must be made for the fact that the singlet represents only 83.1% of the dimethylmercury actually present. Although protons β to the metal in ethyllithium, ethylmagnesium chloride, and butyllithium are obscured by ether or hexane, the quartet (triplet in the case of butyllithium) due to the α-protons are not and can therefore be measured. Because of the phenyl-substituent effect, the methylene protons in benzyl-, *p*-methoxybenzyl-, and *p*-methylbenzylmagnesium chloride cannot be seen in ether or hexane. However, integration of the aromatic protons in these compounds allows the analysis

---

* All δ values are relative to tetramethylsilane.

to be undertaken provided that methylene chloride is used as reference. The aromatic protons of benzyl- and *p*-methylbenzylmagnesium chloride appear as unsymmetrical singlets at δ −6.9 and −6.8 ppm respectively, while those for *p*-methoxybenzylmagnesium chloride produce an AA′BB′ quartet centred at δ −6.7 ppm. In each case the integration is taken over the whole aromatic signal. Because of the rapid exchange encountered in allylmagnesium chloride all the CH_2 protons are equivalent and the spectrum consists of an AX_4 pattern[11]. The A part of this spectrum (the X part is obscured by solvent) is easily recognised as a symmetrical quintet at δ −6.32 ppm. Integration of this signal with reference to benzene standard allows the estimation of allylmagnesium chloride to be made.

Results given in Table 1 show that the NMR determinations are quite self consistent, and in general agreement with the titration figures. The accuracy of the method is limited by the integration process, which is usually considered to be accurate within ±5%. The actual error is probably significantly less than this since samples are measured in triplicate, and an average of four integrations for each sample is taken. Of course this error would diminish considerably if computer averaged techniques were used. However the NMR method compares most favourably with the titration method which in our hands seldom gave reproducibility better than ±5%.

In conclusion it should be noted that the NMR method has the great advantage that it estimates only the organometallic species, rather than total basic content which is given by titration with acid, unless special procedures to eliminate non organometallic bases are undertaken.

ACKNOWLEDGEMENTS

The author gratefully extends his thanks to Messrs. J. Maddock and C. G. Patel for experimental assistance.

REFERENCES

1 J. R. Urwin and P. J. Reed, *J. Organometal. Chem.*, 15 (1968) 1.
2 M. G. Van Campen, D. F. Meisner and S. M. Parmerter, *J. Amer. Chem. Soc.*, 70 (1948) 2296.
3 H. Gilman, J. A. Beel, C. G. Brannen, M. W. Bullock, G. E. Dunn and L. S. Miller, *J. Amer. Chem. Soc.*, 71 (1949) 1499.
4 H. Gilman and R. E. Brown, *J. Amer. Chem. Soc.*, 52 (1930) 3314.
5 H. Gilman, E. A. Zoellner and J. B. Dickey, *J. Amer. Chem. Soc.*, 51 (1929) 1576.
6 H. Gilman and A. H. Haubein, *J. Amer. Chem. Soc.*, 66 (1944) 1515.
7 B. J. Wakefield, *Organometal. Chem., Rev.*, 1 (1966) 131.
8 G. Fraenkel, D. G. Adams and J. Williams, *Tetrahedron Lett.*, (1963) 767.
9 D. F. Evans and J. P. Maher, *J. Chem. Soc.*, (1962) 5125.
10 R. E. Dessy, T. J. Flautt, H. H. Jaffé and G. F. Reynolds, *J. Chem. Phys.*, 30 (1959) 1422.
11 G. M. Whitesides, J. E. Norlander and J. D. Roberts, *Disc. Faraday Soc.*, 34 (1962) 185.