

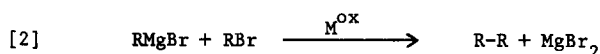
THE ROLE OF IMPURITIES IN THE REACTIONS OF GRIGNARD REAGENTS WITH ALKYL BROMIDES

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(Received in USA 6 April 1973; received in UK for publication 17 July 1973)

It has been established by chemical (2a) and CIDNP (3,4) techniques that some transition metal salts catalyze the reaction of Grignard reagents with alkyl halides by a mechanism involving free radicals. Such catalysis is probably responsible for the Wurtz coupling side reaction which lowers the yield of Grignard reagent obtained when magnesium of low purity is used (2b). We present further evidence here, however, that metal impurities are catalytically active only in an oxidized state and may be so activated by small amounts of oxidizing impurities present in the organic halide or otherwise introduced during formation of the Grignard reagent.

The ordinarily sluggish reaction of isopropylmagnesium bromide with excess freshly distilled isopropyl bromide (Figure 1c) proceeds vigorously after the addition of as little as 3% bromine (based on Grignard reagent), Figure 1a,b. The proposed catalysis due to a synergistic effect of bromine and metal impurities in the magnesium is represented by the reaction sequence



where M represents the collective metallic impurities present in the system.

This mechanism is supported by the following additional observations:

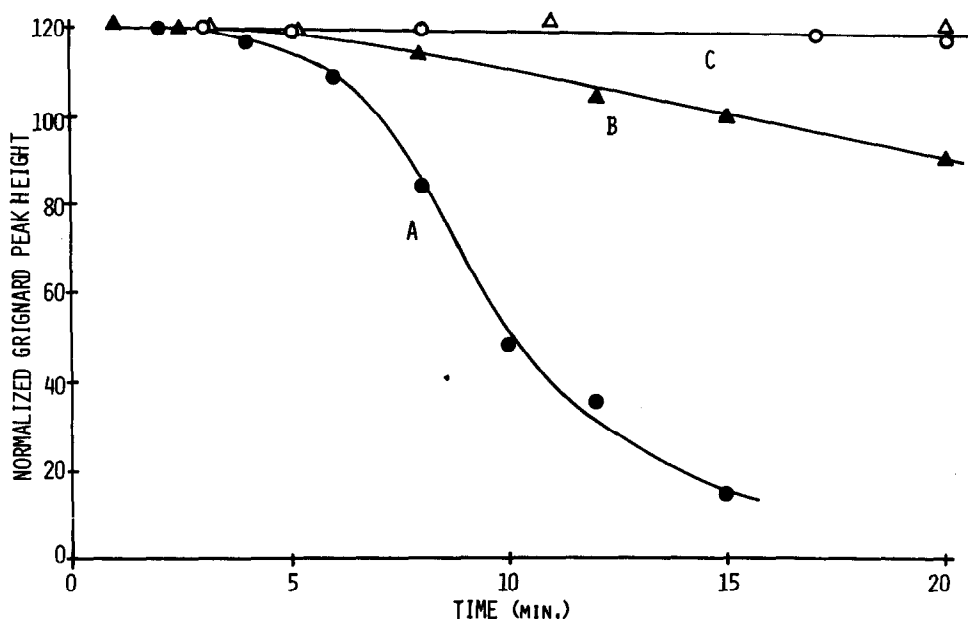


Figure 1 - Effect of magnesium purity on the rate of reaction of isopropylmagnesium bromide (0.7 M) and isopropyl bromide (3.0 M) in the presence and absence of bromine (0.023 M). Reaction conditions: ○, Grignard prepared from 99.9% magnesium, no bromine; △, 99.998% magnesium, no bromine; ●, 99.9% magnesium, bromine added; ▲, 99.998% magnesium, bromine added.

i.) the rate profile in Figure 1a is nearly identical to that produced by the addition of 10 ppm ferrous chloride in place of the bromine;

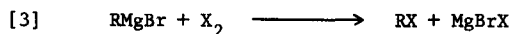
ii.) the addition of styrene inhibits catalysis in both reactions (5);

iii.) the rate acceleration upon bromine addition is greater when lower purity magnesium (6) is used to prepare the Grignard reagent (compare Figure 1, a and b);

iv.) addition of oxygen or iodine also accelerates the reaction;

v.) it is found that when the bromine doped reactions are carried out in the probe of an A-60-A nmr spectrometer, large CIDNP enhancements (AE) are observed for the disproportionation products, propane and propene, demonstrating the intermediacy of freely diffusing isopropyl radicals previously reported for the iron salt catalyzed reaction (3).

It should be noted, of course, that the halogens also react with the Grignard reagent via reaction [3] which competes with [1] for consumption of the halogen.



Since the concentration of metallic impurities, M^0 , in [1] is at least 10^3 times less than the concentration of RMgBr, k_1 must be several orders of magnitude greater than k_3 .

As a further illustration of the ineffectiveness of reduced heavy metals in catalyzing the coupling reaction, it was found that use of an uncoated soft-iron bar magnet for stirring of a magnesium-isopropylbromide mixture in THF resulted in a decrease of only 6% in the yield of Grignard reagent compared to that obtained under identical conditions with a Teflon coated stirring bar. In contrast, the yield was decreased by 22% when the isopropylbromide contained 1% bromine, even when a Teflon coated stirring bar and the purest magnesium available (6) were used!

These results suggest strongly that good yields of a Grignard reagent may be obtained even with impure magnesium provided that the organohalide is free of halogen. They also argue that when impure magnesium is used exclusion of oxygen may be more important for minimizing reaction [1] than it is for preventing oxidation of the Grignard reagent in a reaction like [3]. It also suggests that the addition of iodine as an initiator may actually decrease the overall yield of reagent if low purity magnesium is employed.

Finally, we have found that although the coupling reaction of isopropylmagnesium bromide with isopropyl bromide can be avoided by distillation of the halide, the same is not always true of the more reactive halides. Thus, even freshly distilled t-butyl bromide reacts rapidly with isopropylmagnesium bromide (prepared from magnesium A). The reaction apparently proceeds via a metal-catalyzed free radical pathway since it displays CIDNP (AE) in both the isobutylene and isobutane signals and is quenched by addition of styrene. Presumably distillation does not remove traces of bromine. Fractional freezing of t-butyl bromide however, gives material which reacts more slowly, suggesting this as the method of preference for purification of reactive halides.

Acknowledgements: This work was supported by grants from the National Science Foundation and the Petroleum Research Fund, administered by the American Chemical Society. H. R. W. is pleased to acknowledge a most helpful discussion with Professor H. O. House.

References and Footnotes

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- (5) M. Tamura and J. K. Kochi, J. Organometal. Chem., 31, 289 (1971) observed that added styrene slowed, but did not quench, the rate of the iron catalyzed reaction. They suggested this might be due to irreversible complex formation between styrene and catalytically active organoiron intermediates. We observe a similarly slowed reaction with the same styrene-to-ferrous chloride ratio, but complete quenching of catalysis occurs with greater than 10^{-3} M added styrene (ca. 100 times the added FeCl_2 concentration).
- (6) Magnesium A (99.9% pure) was "Reagent Grade" obtained from Eastman Organic Chemicals, Rochester, N. Y. Magnesium B (99.998% pure) was obtained from Jarrell-Ash Division of Fisher Scientific Co., and bears the trade name "Specpure".