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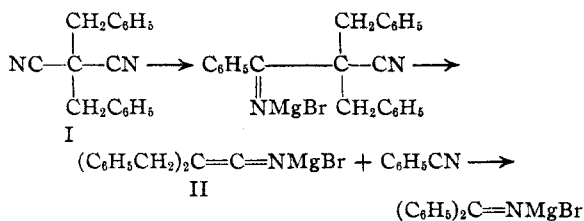
Cleavage by Organic Magnesium Compounds. I. The Cleavage of Malononitriles¹

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It has been shown definitely that various types of compounds undergo cleavage when treated with organic magnesium compounds. Leroide² and later Mirau³ obtained cleavage products from several disubstituted malonic esters. More recently Kohler, Richtmyer and Hester⁴ have shown that α -oxido ketones and glycidic esters undergo cleavage with organic magnesium compounds, and Kohler and Erickson⁵ have reported similar results with β -diketones.

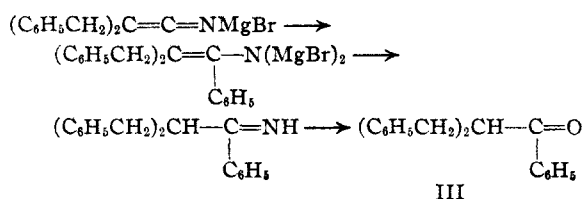
We have observed this type of cleavage with certain malononitriles. These compounds differ from β -diketones in that both acyl groups are replaced by cyanide.

This paper reports a study of the behavior of four malononitriles with phenylmagnesium bromide. Our investigation began with dibenzyl malononitrile I. We added this compound to an ethereal solution of phenylmagnesium bromide and obtained on hydrolysis benzophenone and dibenzyl acetonitrile as cleavage products. The first step in the reaction is addition of the reagent to one of the nitrile groups. The resulting magnesium compound is unstable, and decomposes immediately in a manner presumably like that of the magnesium derivatives from β -diketones.



An examination of the structure of the ketene imine cleavage product II shows that it possesses a twinned double linkage, not unlike that found in ketenes. If the reaction is carried out in ether, II survives for an almost indefinite length of time in the presence of an excess of phenylmagnesium bromide, while benzonitrile, the other cleavage product, reacts with more of the reagent. The magnesium derivatives of ketene imines presum-

ably react in a very sluggish manner, as this is apparently the end of the process. Yet from general considerations,⁶ one would expect this ketene imine to be capable of further reaction with phenylmagnesium bromide, and such was found to be the case. Upon replacing the ether with benzene and operating at a higher temperature, both II and benzonitrile consume more of the reagent to give, upon hydrolysis, excellent yields of dibenzylacetophenone III and benzophenone.



The extent to which cleavage occurs depends entirely upon the stability of the primary Grignard addition product. The extreme ease with which these magnesium derivatives decompose is indeed surprising. If decomposition takes place at all, it usually does so immediately. However, from a comparison of the results obtained by Leroide² and Slavajanoff⁷ with disubstituted malonic and acetoacetic esters, it is reasonable to suppose that the complexity of the Grignard reagent is an appreciable factor. Kuntz and Adkins,⁸ however, in their experiments with dialkyl β -diketones and keto esters, have conclusive evidence that the rate of alkaline alcoholysis varies with the nature of the substituted alkyl groups. Our own experiments with dimethylmalononitrile IV and phenylmagnesium bromide indicate that these groups influence greatly the rate of decomposition of the magnesium derivative. When IV is added to an ethereal solution of phenylmagnesium bromide in the usual manner, cleavage is almost entirely avoided, as the product consists almost wholly of the diketimine of dimethyldibenzoylmethane, with only a trace of benzophenoneimine, but when, inversely, the compound is added to but one equivalent of the reagent, only the cleavage products, benzonitrile

(1) Partly from a thesis submitted by Maxwell M. Barnett to the Faculty of Louisiana State University, August, 1934, in partial fulfillment of the requirements for the degree of Master of Science.

(2) Leroide, *Ann. chim.*, (ix) **16**, 354 (1921).

(3) Mirau, Thesis, Berlin, 1927.

(4) Kohler, Richtmyer and Hester, *THIS JOURNAL*, **53**, 205 (1931).

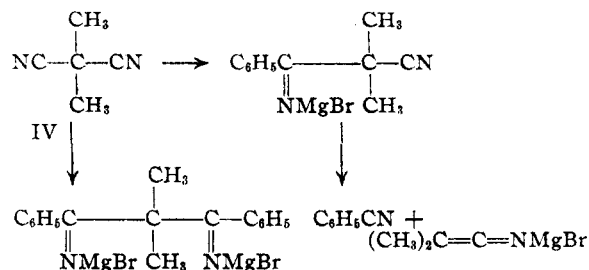
(5) Kohler and Erickson, *ibid.*, **53**, 2301 (1931).

(6) Gilman, Kirby and Kinney, *THIS JOURNAL*, **51**, 2253 (1929).

(7) Slavjanoff, *J. Russ. Phys.-Chem. Soc.*, **39**, 140 (1907).

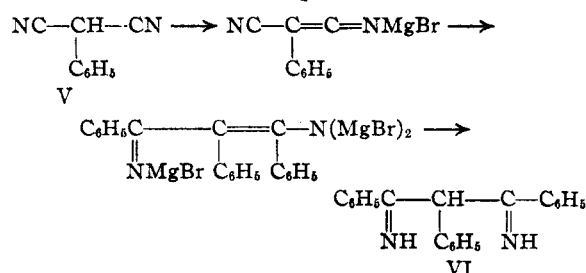
(8) Kuntz and Adkins, *THIS JOURNAL*, **52**, 4391 (1930).

and isobutyronitrile, are obtained, thus affording additional evidence as to the manner in which fission of the molecule occurs.



The extent to which the molecule is cleaved, therefore, depends upon the relative rates of decomposition of the primary magnesium derivative and of addition of more of the reagent to the unattacked cyanide group.

With the monosubstitution products of malononitrile, the outcome is quite definite, but entirely different. Upon adding phenylmalononitrile V to an ethereal solution of phenylmagnesium bromide, all of the material is recovered. Quantitative determinations,⁹ however, show that it liberates one mole of methane. If the operation is carried out at an elevated temperature, three equivalents of the reagent are consumed, and it becomes possible to secure a good yield of a red crystalline substance, which proved to be the diketimine of phenyldibenzoylmethane VI. The reaction then must be represented as follows



Strangely enough, the simplest member of the series, malononitrile itself, forms no addition product with phenylmagnesium bromide. Instead, an insoluble magnesium derivative is obtained, which stubbornly resists further action of a liberal excess of the reagent, even when the operation is carried out at 75°, and for a period of several hours. Upon hydrolysis, an almost quantitative yield of malononitrile is recovered. The reasons for the abnormal behavior of malononitrile are not apparent.

In the above experiments, ketene imines are obtained only in the form of their magnesium

derivatives, which either consume more of the reagent to form ketene imines, or revert to nitriles upon hydrolysis. A study of the alkylation and acylation of these compounds is now in progress in this Laboratory.

Experimental Part

Dibenzylmalononitrile, I.—This compound was prepared from dibenzylcyanoacetamide, using essentially the method of Errera and Berté.¹⁰ An almost quantitative yield of the product, melting at 130–131°, was obtained.

Action of Phenylmagnesium Bromide.—An ethereal solution of phenylmagnesium bromide, containing 3.5 g. of magnesium, was prepared. To this, 7 g. of the nitrile dissolved in ether was added gradually. The resulting mixture was refluxed for one hour, allowed to stand for twelve hours, and hydrolyzed by pouring into ice and hydrochloric acid, care being taken to separate the aqueous and ether layers before they could warm up. From the ether solution, 5.1 g. or a yield of 80% of dibenzylacetone nitrile was obtained, which melted at 92° after recrystallization from alcohol. It was identified by comparison with an authentic sample on hand. The aqueous acid solution contained the hydrochloride of benzophenone-imine, for upon warming the solution gently, benzophenone separated. The yield was quantitative.

In a second experiment, the same quantities of materials were used. After adding the nitrile to the reagent, the ether was gradually displaced by benzene until the temperature rose to 70–80°. The mixture was then refluxed for thirty minutes, cooled and hydrolyzed as before. After the usual operations, which were made difficult by the presence of considerable tarry material, there was obtained 3.1 g. of dibenzylacetophenone III, which melted at 78°, and when mixed with an authentic sample, prepared by the method of Nef,¹¹ the melting point was unchanged. Benzophenone was obtained almost quantitatively from the aqueous layer as before.

Dimethylmalononitrile, IV.—Our method of preparation consisted merely of converting dimethylcyanoacetamide to IV, and differed from the method of Errera and Berté¹² only in the manner in which the amide was obtained. They obtained this compound by methylating cyanoacetamide. We found it an advantage to start with ethyl dimethylcyanoacetate. To 200 cc. of concentrated ammonia was added 41.5 g. of ethyl dimethylcyanoacetate. After standing for twenty hours, the resulting solution was concentrated on the steam-bath. Upon standing, it deposited 14.1 g. of the amide, melting at 106°. From the mother liquor, a second crop of crystals, consisting of 3.5 g., was obtained.

Action of Phenylmagnesium Bromide.—To a solution of phenylmagnesium bromide containing 8.3 g. of magnesium was added gradually 6.4 g. of IV dissolved in ether. Each drop produced a vigorous reaction, accompanied by a slight precipitate, which dissolved immediately. The resulting solution was hydrolyzed at once with iced hydrochloric acid. Needle-like crystals separated, probably

(10) Errera and Berté, *Gazz. chim. ital.*, **26** 11, 221 (1896).

(11) Nef, *Ann.*, **310**, 322 (1900).

(12) Ref. 10, p. 224.

(9) Kohler, Stone and Fuson, *THIS JOURNAL*, **49**, 3181 (1927).

the hydrochloride of the diketimine of dimethyldibenzoylmethane. They hydrolyzed rapidly, the product going into the ether layer. The ethereal solution was concentrated and upon addition of petroleum ether 4.8 g. of colorless crystals separated, which, when recrystallized from alcohol, melted at 99°. When mixed with an authentic sample of dimethyldibenzoylmethane, the melting point was unaltered. Warming of the aqueous layer caused the separation of 1.3 g. of benzophenone.

Action of One Mole of Phenylmagnesium Bromide, Inverse Grignard Reaction.—In this experiment the operations were reversed, and the reaction was carried out below -15°. A solution of phenylmagnesium bromide containing 2 g. of magnesium was added, slowly, to 6 g. of IV dissolved in anhydrous ether. The mixture was allowed to stand for five minutes, and was then decomposed with cold dilute hydrochloric acid. The ether layer gave an oil, which was separated into two fractions by distillation. The first fraction consisted of 5.1 g. of a liquid, boiling at 185–190°, and was identified as benzonitrile by hydrolyzing the product to benzamide. The second fraction, boiling at 104–109°, contained 1.1 g. of isobutyronitrile, which was converted to the corresponding amide for purposes of identification.

Phenylmalononitrile V was prepared from phenyl cyanoacetamide in a manner already described by Hessler.¹³ An ethereal solution of V was added slowly to phenylmagnesium bromide containing 3.3 g. of magnesium. The reaction was quite vigorous, and was accompanied by the formation of a bulky precipitate. The resulting mixture was refluxed for three hours before decomposing with ice and hydrochloric acid. Of the 4 g. of nitrile used, all but 0.1 g. was recovered.

In the next experiment, the same quantities of materials were used, and the operations were carried out in the same manner, except that the ether was displaced by benzene until the temperature rose to 75–80°. This temperature was maintained for a period of two hours, at which time the precipitate originally present had dissolved. Upon hydrolysis with ammonium chloride and cracked ice, an orange-red solid precipitated out. This was collected and washed with concentrated ammonium chloride solution and finally with water to free it from magnesium salts. Upon crystallizing the product from a mixture of methyl alcohol and ether, 4.1 g. of deep red crystals was obtained, which proved to be the diketimine of phenyldibenzoylmethane VI, m. p. 167–168° (with decomposition). The diketimine is soluble in methyl alcohol and acetone; insoluble in water, ether and benzene. The benzene layer gave a small quantity of tarry material, from which no definite products were obtained.

Anal. Calcd. for $C_{21}H_{18}N_2$: C, 84.55; H, 6.06; N, 9.39. Found: C, 84.62; H, 6.13; N, 9.27.

Hydrolysis of the Diketimine, VI.—0.25 g. of VI dissolved in 25 cc. of 20% hydrochloric acid, imparting a reddish color to the solution. Upon heating on a steam-bath, the color faded gradually, a colorless solution remaining at the end of an hour, and a mass of colorless crystals separated. These were collected and dried, and when crystallized from benzene and petroleum ether they melted at 149°. A comparison with an authentic sample of phenyldibenzoylmethane on hand proved them to be identical. The yield was quantitative.

Malononitrile.¹⁴ Action of Phenylmagnesium Bromide.—The nitrile was added to a solution of phenylmagnesium bromide containing 6.1 g. of magnesium. A granular precipitate formed immediately, and settled to the bottom of the flask. The mixture was refluxed for several hours and allowed to stand for twenty hours. The supernatant liquid was then decanted and the precipitate was washed with ether. Hydrolysis was effected with ice and hydrochloric acid. The aqueous solution was extracted with ether by means of a continuous liquid extractor. Of the 6.6 g. of nitrile used, all but 0.5 g. was recovered.

In a subsequent experiment the ether was displaced by benzene, and the reaction mixture heated at 75° for a period of two hours. Similar results were obtained, as the starting material was recovered.

Summary

1. The reactions between phenylmagnesium bromide and dibenzylmalononitrile, dimethylmalononitrile, phenylmalononitrile and malononitrile have been studied.
2. Dibenzylmalononitrile adds one equivalent of the reagent to yield a magnesium compound, which decomposes into two cleavage products; each subsequently then consumes one equivalent of the reagent. Dimethylmalononitrile behaves in a similar manner, and also yields an addition product.
3. Phenylmalononitrile consumes three equivalents of the reagent to form an addition product.
4. Malononitrile forms an insoluble magnesium compound from which the former is recovered upon hydrolysis.
5. Addition of the reagent to a ketene imine linkage is described.

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(13) Hessler, *Am. Chem. J.*, **32**, 123 (1904).

(14) Hesse, *ibid.*, **18**, 725 (1896); "Organic Syntheses," John Wiley and Sons, New York, 1930, Vol. X, p. 66.