

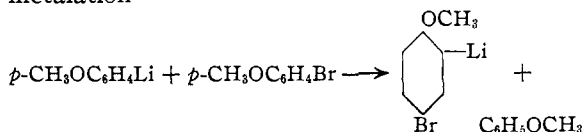
was added equivalent amounts of anisole and *p*-bromoanisole. The mixture was then concentrated to 55 cc., refluxed for twenty hours, and carbonated to yield 30% of 5-bromo-2-methoxybenzoic acid. From a related experiment in which the ether solution was not concentrated, there was isolated a mixture of 5-bromo-2-methoxybenzoic acid and *p*-methoxybenzoic acid.

Acknowledgment.—The authors are grateful to Dr. Ray Q. Brewster for suggestions and samples of some phenyl ether derivatives.

Summary

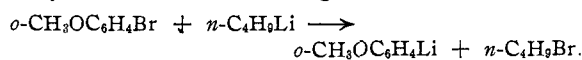
1. Incidental to the preparation of *p*-methoxyphenyllithium, varying amounts of 5-bromo-

2-methoxyphenyllithium are formed by auto-metalation



A related reaction takes place with *p*-bromodiphenyl ether.

2. When *o*-bromoanisole is metalated by *n*-butyllithium the following interchange occurs



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[CONTRIBUTION FROM THE CHEMICAL LABORATORY OF IOWA STATE COLLEGE]

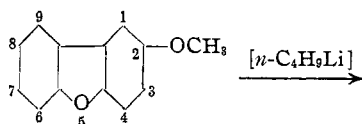
Relative Reactivities of Organometallic Compounds. XX.* Metalation

BY HENRY GILMAN AND ROBERT L. BEBB

Introduction

This paper reports results on the lateral and the nuclear metalations of some compounds, using a variety of organometallic compounds and different media.

2-Methoxydibenzofuran.—The metalation of dibenzofuran by metals, inorganic salts and organometallic compounds invariably has involved the otherwise inaccessible 4-position.¹ Subsequent studies² confirmed the pronounced tendency of metalation to take place ortho to an ether linkage. Substitution of methoxy in the 2-position should make mono-metalation possible in the 1-, 3- or 4-position. We have now shown that metalation does not take place in the expected 4-position. The 60% yield of methoxy acid, formed subsequent to carbonation, was found to consist of about four parts of 2-methoxy-1-dibenzofurancarboxylic acid (m. p. 156°) to one part of 2-methoxy-3-dibenzofurancarboxylic acid (m. p. 206–207°).³



2-CH₃O[C₁₂H₈O]Li-1 and 2-CH₃O[C₁₂H₈O]Li-3

Ethers and Thioethers.—The acids obtained after carbonating the RM products of metalation of anisole, phenyl ether and phenyl sulfide were *o*-methoxybenzoic, *o*-phenoxybenzoic and *o*-phenylmercaptobenzoic acids, respectively.

Metalation of anisole by *n*-butyllithium in ether for twenty hours gave 19%⁴ of acid; by *n*-butylsodium in petroleum ether (b. p., 60–68°) for four days gave a 42% yield; by phenylsodium in benzene for twenty-four hours gave a 44% yield; and by phenylsodium in benzene for forty-eight hours gave a 64% yield.

Metalation of phenyl ether in liquid ammonia by means of ethynylsodium gave as the only acidic material a small quantity of *o*-phenylphenol. The same product was obtained earlier by Späth when phenyl ether was heated with ethylmagnesium bromide at elevated temperatures.⁵ Apropos the series of extremely weak acids,⁶ phenyl ether was not metalated by triphenylmethylsodium. Using *n*-butyllithium the yield of *o*-phenoxybenzoic acid in petroleum ether was 7% at the end of twenty hours and in ether the yields were 54 and 60% at the end of six hours and twenty hours, respectively.

Metalation of phenyl sulfide, by *n*-butyllithium in ether for six hours gave 24% of *o*-phenylmercaptobenzoic acid; by *n*-butyllithium in ether for twenty hours gave 30% of

(* Paper XIX, THIS JOURNAL, 60, 2334 (1938).

(1) Gilman and Young, *ibid.*, 56, 1415 (1934); 57, 1121 (1935).

(2) Gilman, Langham and Jacoby, *ibid.*, 60, 106 (1938); Gilman and Bradley, *ibid.*, 60, 2333 (1938); Wittig, Pockels and Dröge, *Ber.*, 71, 1903 (1938).

(3) The authors are grateful to P. R. Van Ess for authentic specimens of these two acids.

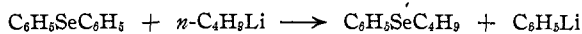
(4) An unusually high yield (40%) of di-*o*-methoxyphenyl ketone was isolated. Under corresponding conditions of carbonation, the yield of benzophenone from phenyllithium is 15.4%; Gilman and Van Ess, THIS JOURNAL, 55, 1258 (1933).

(5) Späth, *Monatsh.*, 35, 319 (1914).

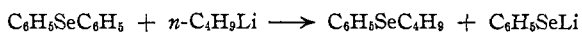
(6) Conant and Wheland, THIS JOURNAL, 54, 1212 (1932); McEwen, *ibid.*, 58, 1124 (1936).

acid; and by phenylsodium in benzene for forty-eight hours gave 56% of acid.

Phenyl Selenide.—A comparison of the related phenyl ether, phenyl sulfide and phenyl selenide reveals two trends. First, the extent of cleavage increases, from a trace of thiophenol from the sulfide to a larger amount of selenophenol from the selenide. Second, the amount of metalation decreases sharply and to such an extent that none was observed with the selenide. Instead, the predominant reaction in ethyl ether is



The *n*-butyl phenyl selenide was characterized by means of the dibromide derivative. The cleavage reaction leading to the small amount of selenophenol may have been the following



The decrease in metalation and the increase in cleavage appear to be general as one descends in a given group of the periodic table, and the prediction may be made that fluorobenzene will be metalated more and cleaved less than iodobenzene.

Biphenyl.—Metalation of biphenyl took place to a limited extent, and the acid obtained subsequent to carbonation was *p*-phenylbenzoic. With *n*-butyllithium in ether and refluxing for twenty hours the yield was 7–15%, most of the biphenyl being recovered; and with *n*-butylsodium for twenty hours at room temperature, in petroleum ether (b. p. 30–40° or 60–68°), the yield was 5%.

Diarylmethanes.—The lateral metalation observed with these types appears to be affected significantly by the nature of the aryl group. Under corresponding conditions, using *n*-butyllithium in ether, the yield of diphenylacetic acid from the diphenylmethane was 20%; the yield of phenyl-*p*-tolylacetic acid from phenyl-*p*-tolylmethane was 50%; and the yield of phenyl- α -naphthylacetic acid from phenyl- α -naphthylmethane was 80%. In the latter experiment a brilliant red solution formed shortly after the reactants were mixed, and the color deepened as the reaction proceeded but disappeared instantly on carbonation.

Bibenzyl.—The direction of metalation of bibenzyl varied with the nature of the organoalkali compound. Both *n*-butylsodium and *n*-butylpotassium gave lateral dimetalation, the product from carbonation being α,β -diphenylsuccinic acid.

Metalation by *n*-butylsodium in tri-*n*-butylamine for twenty-four hours gave a 30% yield of acid; metalation by *n*-butylsodium in benzene for forty-eight hours gave a

50% yield; and metalation by *n*-butylpotassium in benzene for twenty-four hours gave a 52% yield.

With *n*-butyllithium, metalation took place to a limited extent (1%). Separation of the acids obtained subsequent to carbonation, and then oxidation to phthalic acids showed that nuclear monometalation occurred in the meta and in the para positions. The para acid, *p*-(β -phenylethyl)-benzoic acid, may have formed as a consequence of allylic rearrangement of a lateral monometalation intermediate. This reaction is being examined further with the moderately reactive organometallic compounds.

Some Polynuclear Types.—The mixture of acids obtained from the metalation of naphthalene was resolved into α -naphthoic and β -naphthoic acids, in the ratio of about 2.5:1.

Metalation by *n*-butyllithium in ether for fifteen hours and thirty-six hours gave 13 and 20% yields, respectively, of the mixture of acids; metalation by phenyllithium in ether for forty-eight hours gave 5% of the acids; metalation by *n*-butylsodium in tri-*n*-butylamine for thirty-six hours gave 28% of the acids; and metalation by phenylsodium in benzene for forty-eight hours gave 5% of the acids.

Metalation of acenaphthene by *n*-butyllithium in ether gave a mixture of mono- and dibasic acids which has not yet been separated. Decarboxylation by heating with calcium oxide and copper gave acenaphthene; and oxidation by dichromate gave naphthalic acid. There was no evidence of dehydrogenation⁷ of the acenaphthene by the *n*-butyllithium.

There was also no evidence of dehydrogenation when 9,10-dihydroanthracene was heated for thirty-six hours with two equivalents of *n*-butyllithium. The two acids isolated were 8% of 9,10-dihydro-9,10-anthracenedicarboxylic acid and 80% of 9,10-dihydro-9-anthracenecarboxylic acid.

The trace of acid resulting from the reaction mixture obtained intermediately from phenanthrene and phenyllithium was shown to be 9-fluorenicarboxylic acid. This supports the observations of others⁸ that fluorene is a contaminant in some specimens of phenanthrene.

Dibenzothiophene.—Dibenzothiophene is the most sensitive polynuclear compound so far examined for selective or preferential metalations.⁹ The results now reported are an extension of metalations with new RM types and different solvents.

(7) Gilman and Bradley, *THIS JOURNAL*, **60**, 2333 (1938).

(8) Jeanes and Adams, *ibid.*, **59**, 2608 (1937). See also Ziegler and Bähr, *Ber.*, **61**, 261 (1928).

(9) Gilman and Jacoby, *J. Org. Chem.*, **3**, 108 (1938).

It is particularly noteworthy that a 90% yield of 4-dibenzothiophenecarboxylic acid was obtained by metalation with *n*-butyllithium in di-*n*-butyl ether.

Metalation by *n*-butyllithium in *n*-butyl ether for twenty-four hours at room temperature and at 80°, respectively, gave yields of 61 and 90% of acid; metalation by *n*-amylsodium in petroleum ether (b. p. 60–68°) for six hours gave 37% of acid; and metalation by phenylsodium in benzene for twenty hours gave 23% of acid.

No metalation was observed with triphenylmethylsodium. The following solvents were found ineffective under our experimental conditions and with the use of *n*-butyllithium: petroleum ether (b. p. 30–35° and 60–68°), benzene and dioxane.

Furans.—The yield of 2-furoic acid obtained subsequent to metalation of furan by phenyllithium was first shown to be the same (about 40%) as that obtained earlier.¹⁰ Then 7.5% of 2-furoic acid was isolated from a metalation with methylithium in ether over a four hour period.

With 2-methylfuran and *n*-butyllithium over a period of four and one-half hours, the yield of 5-methyl-2-furoic acid was 17%. A 29% yield of the same acid was obtained after heating for twenty-four hours with phenyllithium.

Alkynes in Liquid Ammonia.—The orienting experiments with alkynes were carried out in order to throw light on the relative acidities of acetylene, 1-heptyne and phenylacetylene. First, it was shown that ethynylsodium and ethynylpotassium did not metalate 1-heptyne appreciably. After allowing the reactants to stand for a time, benzophenone was added. From the ethynylsodium experiment there was obtained an 89% yield of diphenylethynylcarbinol and none of the carbinol containing the heptynyl group. The yield of diphenylethynylcarbinol from the ethynylpotassium experiment was 60–77%, and the yield of tetraphenylbutynediol¹¹ was 18%.

Second, ethynylsodium did metalate phenylacetylene. In this experiment, ether was added as the solvent for the reaction with benzophenone, and the yield of phenylethynyl-diphenylcarbinol was 83%.

Third, heptynylsodium metalated phenylacetylene slightly as evidenced by the very small quantity of phenylethynyl-diphenylcarbinol which was

(10) Gilman and Breuer, *THIS JOURNAL*, **56**, 1123 (1934).

(11) The authors are grateful to M. R. McCorkle for an authentic specimen.

isolated. In an experiment carried out to establish whether the reverse reaction occurred, heptyne was allowed to react with phenylethynylsodium. After treatment with benzophenone, the compounds isolated were phenylethynyl-diphenylcarbinol and a 70% recovery of heptyne.

On the basis of these experiments it appears that the order of decreasing acidity is: $C_6H_5C\equiv CH$, $C_6H_{11}C\equiv CH$, $HC\equiv CH$.

Some experimental details and miscellaneous metalations follow.

Preparation of RM Compounds.—The organolithium compounds were prepared by conventional procedures.¹² *n*-Amylsodium was prepared in accordance with the directions of Morton.¹³ Phenylsodium was obtained by interaction of chlorobenzene and sodium,¹⁴ powdered sodium rather than wire being used. A small amount of *n*-butyl chloride was used as a starter in the preparation of phenylsodium in petroleum ether.¹⁵ Triphenylmethylsodium was prepared by Bachmann's procedure.¹⁶

Reaction Procedure.—The metalations were carried out by conventional procedures, details of which are available in earlier accounts in this series. Carbonation was generally effected by the jet-wise addition to powdered carbon dioxide. The color test^{17a} for organometallic compounds was used to follow the course of reaction, and the solutions were standardized by the acid-titration procedure.^{17b}

***n*-Hexadecane and Cyclohexene.**—No metalation of hexadecane by *n*-butylsodium was observed in benzene, petroleum ether, and no solvent other than the hexadecane. In extension of the present studies on metalation, the more reactive organorubidium and organocesium compounds are being used with both aliphatic and aromatic types. *n*-Butyllithium did not metalate cyclohexene after refluxing for twelve hours.

Dimethylaniline.—Metalation of dimethylaniline by *n*-amylsodium with petroleum ether as a medium gave *N,N*-dimethylantranilic acid. The same product was obtained earlier by Morton¹⁸

(12) Gilman, Zoellner and Selby, *THIS JOURNAL*, **54**, 1957 (1932); **55**, 1252 (1933); Gilman, Zoellner, Selby and Boatner, *Rec. trav. chim.*, **54**, 584 (1935).

(13) Morton and Hechenbleikner, *THIS JOURNAL*, **58**, 1697 (1936).

(14) Bockmühl and Ehrhart, French Patent 736,428 [*Chem. Zentr.*, **104**, II, 2193 (1933)]; Ziegler, *Angew. Chem.*, **49**, 457 (1936).

(15) Unpublished studies by A. L. Jacoby.

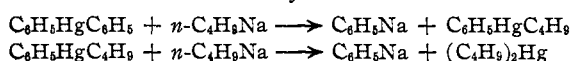
(16) Bachmann and Wiselogle, *THIS JOURNAL*, **58**, 1943 (1936).

(17) (a) Gilman and Schulze, *ibid.*, **47**, 2002 (1925); (b) Gilman, Wilkinson, Fishel and Meyers, *ibid.*, **45**, 150 (1923).

(18) Morton and Hechenbleikner, *ibid.*, **58**, 2599 (1936).

when amyl chloride was added to a mixture of sodium and dimethylaniline in ligroin.

Diphenylmercury.—From a reaction between *n*-butylsodium and diphenylmercury in petroleum ether there was obtained after carbonation a 40% yield of benzoic acid and a 48% recovery of diphenylmercury. The large yield of benzoic acid could not have come from the action of sodium (used to prepare *n*-butylsodium) and diphenylmercury, because the excess sodium was removed by free mercury prior to adding the diphenylmercury. This interchange reaction of organometallic compounds might have involved the intermediate formation of an unsymmetrical mercurial.



Sodium Phenoxide.—There was no evidence of metalation when sodium phenoxide was treated with *n*-butylsodium in a medium of petroleum ether, for three days at room temperature.

General Considerations.—(1) Where comparisons can be made, the extent of metalation increases with the reactivity of the RM compound. This is particularly true when there are possibilities of mono- and polymetalation, the moderately reactive types rarely showing polymetalation. (2) The best solvents, of those so far examined, are the simple ethers.¹⁹ Unfortunately, the more

(19) The effect of ethers with higher oxygen content will be re-

reactive RM compounds cleave ethers. An examination of some of the results now reported reveals that this cleavage reaction may be of secondary importance where the rate of metalation is more rapid than the rate of cleavage, and where the new RM compound formed subsequent to metalation is known to cleave ethers to a limited extent. Although tri-*n*-butylamine was used successfully in some cases as a medium, it appears to suffer the disadvantages of ethers. For example, in an experiment with *n*-butylsodium the yield of *n*-octane was in excess of 100%, and this indicates definite cleavage of the amine by the RNa compound. (3) There are marked correlations between rates of metalation and the rates of cleavage of RM compounds by hydrogen chloride. These will be presented later together with mechanisms correlating metalation with other substitution reactions.

Summary

A series of compounds has been metalated by different organometallic compounds in various media. Interpretations and generalizations of the reactions have been presented.

ported later. Ethers like dimethylglycol ether have been found very effective for addition of alkali metals [Scott, Walker and Hansley, *THIS JOURNAL*, **58**, 2442 (1936)]. The authors are grateful to Dr. Scott for a supply of this particular ether.

AMES, IOWA

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[CONTRIBUTION FROM DEPARTMENT OF CHEMISTRY, DICKINSON COLLEGE]

The Viscosity of Solutions of Sulfur Dioxide in Organic Liquids

BY H. E. ADAMS AND H. E. ROGERS

Research on the viscosity of solutions of gases and liquids has been almost entirely neglected. Lewis¹ investigated solutions of sulfur dioxide in carbon tetrachloride, methyl alcohol, benzene, acetone, toluene and ether and found that the viscosities of liquids are changed by saturating with gases.

This paper presents additional data concerning the effect of dissolved sulfur dioxide on the viscosity of carbon tetrachloride, chloroform and bromoform.

Experimental Part

The carbon tetrachloride was dried over anhydrous calcium chloride and fractionated: b. p. 76.7°; d_{25}^{25} , 1.5845.

(1) J. R. Lewis, *THIS JOURNAL*, **47**, 626 (1925).

The chloroform was washed three times with concentrated sulfuric acid, followed by a solution of sodium hydroxide and finally water. It was then dried over anhydrous potassium carbonate and fractionally distilled, the fraction boiling within a 0.1° interval being collected: b. p. 61.2°; d_{25}^{25} , 1.480.

The bromoform was shaken five times with concentrated sulfuric acid, followed by sodium hydroxide solution and water. It was dried over anhydrous potassium carbonate and distilled at reduced pressure: d_{25}^{25} , 2.864. A slight yellow color developed.

Sulfur dioxide was obtained, in cylinders, from the Fisher Scientific Company. It was passed over anhydrous calcium chloride and through cotton before being used.

Apparatus.—The viscosimeter used was a modification of the Ostwald type. It was made according to details given by Lewis¹ (p. 633) in the second part of his paper. Carbon tetrachloride was used for standardizing the viscosimeter. Since, in adding the sulfur dioxide to the vis-