TABLE V-B

Initial charge in 12-oz. bottle:
31.98 g. cyanobutadiene
48.0 g. butadiene
0.4511 g. dodecyl mercaptan
140.0 g. 3% solution of P. & G. SF Flakes
8.00 ml. 3% solution of $K_2S_2O_8$

Reaction time hr.	Fractional conversion		Nitrogen in polymer, %		Weight fraction of cyanobutadiene in polymer
4.5	0.409 .410	0.410			
6	.443 .449	.446	12.08 12.15	12.12	0.6844
8	.491 .496	.494	11.69 11.76	11.72	.6618
10	.543 .546	.544	11.12 11.13	11.12	.6279
25.5	.951	.951	7.74 7.80	7.77	.4388

TABLE V-C

Initial charge in 12-oz. bottle:
47.92 g. cyanobutadiene
32.0 g. butadiene
0.4256 g. dodecyl mercaptan
140.0 g. 3% solution of P. & G. SF Flakes
8.00 ml. 3% solution of $K_2S_2O_8$

Reaction time, hr.	Fractional conversion		Nitrogen in polymer, %		Weight fraction of cyanobutadiene in polymer
0					
4	0.474 .483	0.478	13.54 13.66	13.60	0.7680
5.5	.625 .627	.626	13.01 13.13	13.07	.7381
7	.690 .696	.693	12.77 12.77	12.77	.7211
8	.730 .730	.730	12.68 12.73	12.70	.7172
25.5	.913 .922	.918	11.06 11.12	11.09	.6262

necessary to have more data than are available at present.

Summary

Copolymerizations of butadiene with various other monomers have been carried out in emulsion systems. It is found that the copolymerization equations of Mayo and others have empirical validity for all of the systems examined. The equations are also believed to be theoretically significant in most cases, an exception being butadiene with acrylonitrile. The anomalous results obtained for that pair are attributed to the high solubility of acrylonitrile in water.

URBANA, ILLINOIS RECEIVED AUGUST 9, 1947

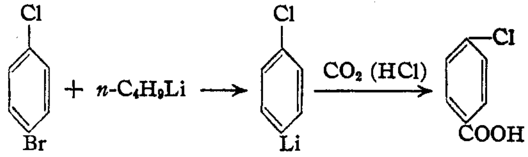
[CONTRIBUTION FROM LOS ALAMOS SCIENTIFIC LABORATORY]

The Application of the Halogen-Metal Interconversion Reaction to Syntheses with Isotopic Carbon[1]

BY ARTHUR MURRAY, III, W. W. FOREMAN AND WRIGHT LANGHAM

The extensive application of the halogen-metal interconversion reaction to a wide variety of aryl halides has resulted in the preparation of organometallic compounds having additional functional groups.[2a,b,c,d]

Because of the rapidity of the reaction, the halogen-metal interconversion between an alkyllithium compound and an aryl halide is uniquely suited to the preparation of organolithium compounds with additional functional groups. As an example, *p*-chlorobromobenzene and *n*-butyllithium react to give a 90% yield of *p*-chlorophenyllithium in ten minutes.[2a] Subsequent carbonation results in the formation of the corresponding carboxylic acids according to the reaction.



The use of isotopic carbon in biological studies is complicated by the relatively small quantities of isotope available and by the unavoidable high dilution of the isotope when introduced into biological systems. In order to conserve isotopic carbon and to achieve maximum specific activity required for certain investigations, we have adapted the halogen-metal interconversion reaction to the micro synthesis of certain compounds of biological significance.

p-Aminobenzoic acid, labelled with C^{14} in the carboxyl group, was prepared by an adaptation of the reaction of Gilman and Stuckwisch.[3a,b] The *p*-aminophenyllithium derivative[4] was isolated and washed free of *n*-butyllithium before carbonation with gaseous $C^{14}O_2$.

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[1] This paper is based on work performed under contract W-7405-Eng-36 with the Atomic Energy Commission at the Los Alamos Scientific Laboratory of the University of California.

[2] (a) Gilman, Langham and Moore, THIS JOURNAL, **62**, 2327 (1940); (b) Langham, Brewster and Gilman, *ibid.*, **63**, 545 (1941); (c) Gilman, Langham and Willis, *ibid.*, **62**, 346 (1940); (d) Gilman and Gainer, *ibid.*, **69**, 1946 (1947).

[3] (a) Gilman and Stuckwisch, *ibid.*, **63**, 2844 (1941); (b) Gilman and Stuckwisch, *ibid.*, **64**, 1007 (1942).

[4] This compound is believed to be *p*-$LiC_6H_4N(Li)_2$. C. G. Stuckwisch, private communication.

Good yields of carboxyl-labelled nicotinic acid were obtained by the method of Gilman and Spatz,[5] when the reaction was scaled down to the millimole level and adapted to carbonation with gaseous carbon dioxide.

Experimental

Apparatus and General Procedure.—A compact vacuum system was designed and constructed as outlined in Fig. 1. The total volume of the system was kept at a minimum. The apparatus was attached at (V) to an oil pump by means of a three-way stopcock that permitted independent evacuation of both main sections of the system. A source of dry carbon dioxide and oxygen-free nitrogen was attached to the system at (N).

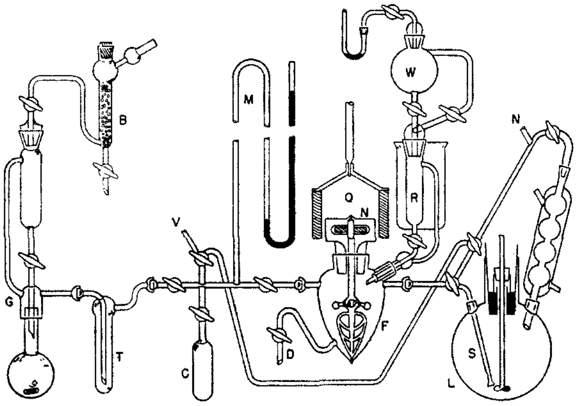

Fig. 1.—Apparatus for the preparation and gaseous carbonation of organolithium compounds.

After evacuation isotopic carbon dioxide was prepared in generator (G) by slowly adding outgassed concentrated sulfuric acid to isotopic barium carbonate. The stopcock involved was lubricated with a paste of paraffin and mineral oil. Quantitative evolution of carbon dioxide was attained by warming the acid and stirring by means of a magnet and glass encased iron core. The gas was passed through a trap (T), immersed in a Dry Ice–acetone bath, and condensed in storage bulb (C) by means of liquid air. Any non-condensable gas was pumped off.

The required volume of *n*-butyllithium[2a] solution (assayed before every run by the differential titration method of Gilman and Haubein[6]) was transferred from the preparation flask (L) to the calibrated cone-shaped reaction flask (F) which had been previously evacuated, flamed and swept out with nitrogen gas. The transfer was made by applying a positive pressure of nitrogen, thus forcing the solution through a filter of glass wool in siphon (S). The addition tube (R), equipped with an outside jacket for a Dry Ice–acetone cooling mixture, was filled with the aryl halide in ether solution. This solution was added to the *n*-butyllithium in flask (F) which had been filled with nitrogen. Moderate stirring was achieved by means of a vacuum-tight glass-enclosed magnetic induction stirrer (N) motivated by two motor-driven permanent bar magnets (Q). In cases where the aryllithium compound was washed free of excess *n*-butyllithium, a siphon (D) controlled by a stopcock was used for drawing off supernatant liquid into an evacuated flask immersed in a freezing bath. Wash ether was stored over sodium wire in reservoir (W) and was added through the addition tube (R).

Before carbonation the reaction flask (F) was cooled to −80°, and pumped down to the vapor pressure of ether. The storage bulb (C) was then warmed and carbonation effected by opening the stopcock connecting the bulb with the reaction flask (F). The absorption of carbon dioxide was followed by observing the fall in pressure on the manometer (M). Rapid stirring of the reaction mixture facilitated the absorption of the gas. When the pressure became constant, the reaction mixture was alternately frozen solid with liquid air and then thawed several times. Unabsorbed gas was then distilled back into the storage bulb (C) and nitrogen was admitted to the reaction flask. The addition tube (R) was quickly filled with dilute acid. The mixture was hydrolyzed while still cold by adding the dilute acid from (R) to the well stirred solution. Any liberated carbon dioxide was frozen back into the storage bulb (C) from which it was recovered, at convenience, by sweeping out the system with nitrogen through the absorption column (B).

***p*-Aminobenzoic Acid.**—To 23.8 mM. of *n*-butyllithium in 29 ml. of ether was added 4.74 mM. of vacuum dried *p*-bromoaniline in 8 ml. of ether. The *p*-bromoaniline was added over a five-minute period, and the reaction mixture cooled during the addition. Stirring was continued at room temperature for one and one-half hours after the bright yellow precipitate of the aryllithium compound first appeared. This precipitate began to form in twenty to ninety minutes, depending upon the age of the *n*-butyllithium. The yields were unaffected by varying the reaction time from one to three hours. The *p*-aminophenyllithium was washed several times with anhydrous ether. The supernatant liquors were siphoned off under nitrogen into an evacuated flask immersed in a Dry Ice–acetone mixture (the dry *p*-aminophenyllithium derivative is explosive in contact with air[4]). Carbonation was effected with 1.029 mM. of carbon dioxide (2 millicuries of C^{14}) of which 32.5% was recovered. The reaction mixture was hydrolyzed with 8 ml. of 6 *N* hydrochloric acid. The strongly acidic reaction mixture was transferred to a modified Soxhlet and continuously extracted with ether for eight hours. The ether phase was discarded. The aqueous phase was made strongly alkaline with potassium hydroxide and again extracted for eight hours. The aqueous phase was then adjusted to *p*H of 3 and the *p*-aminobenzoic acid extracted with ether (sixteen hours). The crude yield of product was 32.8% based on the barium carbonate or 48.2% based on the carbon dioxide absorbed in the reaction. Recrystallization from water gave 35 mg. of colorless needles (m. p. 184–185°). The final product had a specific activity of approximately 30 million disintegrations per minute per mg.

Similar experiments with 1.01–1.59 mM. of ordinary carbon dioxide consistently gave yields of 31.3–38.5%. Ether extraction was found to be superior to the formation of the copper and silver salts for isolating the small amounts of product.

3-Pyridine-carboxylic Acid (Nicotinic Acid).—To 1.63 mM. of *n*-butyllithium in 2.76 ml. of ether cooled to −35° was added, over a four-minute period, 2.44 mM. of redistilled 3-bromopyridine in 5 ml. of ether (also cooled to −35°). Carbonation was effected after one minute, with 0.81 mM. of isotopic carbon dioxide (one millicurie of activity, 160.8 mg. barium carbonate) at −80°. The reaction mixture was quickly hydrolyzed with 3 ml. of 2.5 *N* nitric acid. The acid phase was placed in a modified Soxhlet and continuously extracted with ether (three to four hours), then made alkaline and re-extracted (four to six hours). The crude product was then isolated by adjusting the aqueous phase to *p*H of 3 and continuing the extraction for twenty-four to forty-eight hours. The yield of crude material was 62.4% based on the weight of barium carbonate or 70.3% based on carbon dioxide absorbed. Vacuum sublimation and recrystallization from methanol yielded 30 mg. of colorless powder, m. p. 225–228° (authentic purified specimen m. p. 228–229°). The specific activity of the purified material was approximately 16 million disintegrations per minute per mg.

By the above methods, two different experiments were carried out with 10.6 and 10.4 mM. of $C^{13}O_2$[7] (approx. 6 isotopic per cent. C^{13}) and the same ratio of reagents used

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(5) Gilman and Spatz, This Journal, **62**, 446 (1940).

(6) Gilman and Haubein, *ibid.*, **66**, 1515 (1944).

(7) The $BaC^{13}O_3$ was kindly supplied by Dr. Howard W. Bond of the National Institute of Health.

above. The combined reaction mixtures gave a crude yield of 81.9%. Purification by means of the silver salt gave 55.4% of pure acid (m. p. 227–229°).

Acknowledgment.—We gratefully acknowledge the assistance of Dr. Henry Gilman in whose laboratory one of the authors spent several days becoming acquainted with the latest techniques of handling organolithium compounds. We also acknowledge helpful suggestions from Dr. C. G. Stuckwisch.

Summary

The halogen–metal interconversion reaction between the appropriate aryl halide and *n*-butyllithium has been applied on a one millimole scale to the preparation of *p*-aminobenzoic and nicotinic acids marked in the carboxyl groups with C^{14}. These biologically important compounds have been prepared with extremely high specific activities.

Nicotinic acid containing approximately 6 isotopic per cent. of C^{13} in the carboxyl group was also prepared by the same procedure.

LOS ALAMOS, NEW MEXICO RECEIVED JULY 29, 1947

[CONTRIBUTION FROM THE DEPARTMENT OF CHEMISTRY, UNIVERSITY OF NOTRE DAME]

Some Systems of Silicon Halides with Dioxane

BY S. M. SCHOLASTICA KENNARD[1] AND P. A. MCCUSKER

Molecular compounds of dioxane with inorganic halides, in dioxane solution and in the crystalline state, have been the subject of previous studies in these laboratories[2,3] and elsewhere.[4]

Most of these molecular compounds, whose dielectric properties have been studied in solution, appear to be formed as a result of coördination between dioxane and the central atom of the halide. It has been further observed that those halides which coördinated strongly with dioxane in solution also formed relatively stable crystalline complexes. Since silicon tetrachloride gave no evidence of coördination with dioxane in solution, it was considered of interest to determine whether any solid molecular compounds would be formed between silicon tetrahalides and dioxane. For this reason a study was made of the solid–liquid equilibria in silicon tetrahalide–dioxane systems. Dielectric constant and density data were also obtained for silicon tetrabromide in solution. During the course of this work it became desirable to obtain melting point–composition data for the cyclohexane–dioxane system.

Experimental

Preparation and Purification of Materials.—Dioxane was purified as described previously.[2] Silicon tetrabromide was prepared by passing bromine in a stream of nitrogen over granular silicon, in a vertical, 24 mm. Pyrex tube electrically heated. The exothermic reaction was maintained, with slight heating, by a rapid flow of bromine over the heated silicon. Under carefully controlled conditions silicon tetrabromide, essentially free of bromine, was distilled out of the reaction tube. Purification was effected by shaking with mercury and several distillations in a 4 ft. glass helix-packed distilling column. The final product boiled at 154° and was further purified by fractional freezing. The purity was established by separating into two fractions each melting sharply at 5.4°. The melting point reported by Pohland[5] for highly purified silicon tetrabromide is 5.2–5.3°. Silicon tetrachloride was prepared by a similar procedure and purified by fractional distillation. C. P. cyclohexane was refluxed over phosphorus pentoxide and fractionally distilled.

Determination of Melting Points.—Temperatures were measured with a calibrated tenth-degree mercury thermometer. The apparatus for the determination of the melting points was designed for convenience and rapidity in obtaining data. A motor-actuated reciprocating glass ring stirrer surrounded the bulb of the thermometer immersed in the liquid. The system contained a side arm through which measured volumes of liquid could be added from a buret. A thin rubber finger was used to connect the stirring rod and its glass shaft and permitted the complete exclusion of moisture. In a typical determination, a measured volume of liquid was run into the apparatus and a cooling bath placed around the tube. The liquid was cooled and stirred slowly so as to obtain considerable undercooling. In all this work undercooling of from 5 to 10° was readily obtained. The undercooling is an essential feature of this method of determining melting points. By intermittent application of a bath, held at about 10° below the expected melting point, and control of the rate of stirring, sufficient undercooling could be obtained to cause separation of a large quantity of solid in finely divided form. When solid separated, the bath was removed and the mixture allowed to warm up while being vigorously stirred. With finely divided solid and rapid stirring equilibrium between solid and liquid was closely approached. The equilibrium temperature was taken as the point of visible clarification of the mixture and this temperature checked by observation of the increased rate of temperature rise. In all cases these two readings checked within the precision of the thermometer, and numerous checks demonstrated the reproducibility of the data. Subsequent addition of measured volumes of a second component enabled a considerable number of determinations to be made with one original charge. Warming curves were obtained in a similar manner, temperature–time readings being taken during the warming and vigorous stirring of the mixture, after considerable solid had separated.

Dielectric Constants and Densities.—These were determined as previously described.[2] The molar refraction for silicon tetrabromide was computed from the density and refractive index data of Pohland[5] and this value used for the electron polarization. Ten per cent. of the electron polarization was taken as the value for the atomic polarization. The method of Hedestrand[6] was used for calculat-

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(1) Sister M. Scholastica, C.S.C. Present address: St. Agnes Convent, Los Angeles, California.

(2) Lane, McCusker and Curran, THIS JOURNAL, **64**, 2076 (1942).

(3) Kelley and McCusker, *ibid.*, **65**, 1307 (1943).

(4) Rheinboldt, Luyken and Schmittmann, *J. prakt. Chem.*, **148**, 81 (1937).

(5) Pohland, *Z. anorg. allgem. Chem.*, **201**, 265 (1931).

(6) Hedestrand, *Z. physik. Chem.*, **B2**, 428 (1929).