dissolved in 30 ml of water. This solution was acidified with 10 ml of 50% sulfuric acid. The solution deposited the crude diacid as colorless crystals. One recrystallization from 20 ml of water afforded 3.75 g (88%) of the diacid **6**, mp 165–169°. An analytical sample was prepared by recrystallizing a small portion again from water, mp 166.5–168°.

Anal. Calcd for $C_{10}H_{12}O_4$: C, 61.21; H, 6.17; neut equiv, 98.1. Found: C, 61.12; H, 5.98; neut equiv, 99.3.

The nmr spectrum of **6** was obtained as a 5% solution in trifluoroacetic acid with tetramethylsilane as an external standard. It shows three singlets at τ 4.29, 7.10, and 7.35 with relative intensities of 1:2:2. The lowest field peak is attributable to vinyl hydrogen and the remaining singlets to cyclopentene and cyclobutane methylene protons. The infrared spectrum (potassium bromide disk using a Perkin-Elmer Infracord recording spectrophotometer) showed absorption bands at 1705 (C=O) and a broad envelope band in the region 2700–3500 cm^{-1} attributable to a combination of O—H and C—H stretching vibrations.

Spiro[3.4]-6-octene-2-carboxylic Acid (7). A. Pyrolytic Decarboxylation without Solvent.—A 0.900-g (0.00459 mole) sample of diacid **6** was placed in a sublimator fitted with a cold finger well which was filled with Dry Ice and acetone. The sample was heated to 185° at atmospheric pressure. At this temperature the diacid underwent thermal decarboxylation and monoacid **7** condensed on the cold finger and on the upper side walls of the sublimator. Considerable polymerization occurred during the decarboxylation. The crude monoacid was recrystallized from dilute acetic acid affording in two crops, 0.675 g (56%) of colorless crystals, mp 35–38.5°. A small sample recrystallized from dilute acetic acid showed a melting point of 36–37°.

Anal. Calcd for $C_9H_{12}O_2$: C, 71.02; H, 7.95; neut equiv, 152. Found: C, 71.08, 71.03; H, 8.49, 8.48; neut equiv, 151.7.

B. Decarboxylation in Boiling Pyridine.—Diacid **6** (2.15 g, 0.0110 mole) was dissolved in 12 ml of pyridine and boiled under reflux for 5.5 hr. The solution was cooled, acidified with 28 ml of 6 *N* hydrochloric acid, and continuously extracted with ether for 18 hr. The ether extract was dried and concentrated leaving 1.67 g of the monoacid as a brown solid, mp 25–29°. This sample was dissolved in ether, treated with activated charcoal, filtered, and concentrated to give the nearly colorless acid (1.59 g, 95%), mp 32–36°.

Methyl Spiro[3.4]-6-octene-2-carboxylate (8).—The ester was prepared by dropwise addition of an ethereal solution of diazomethane[12] to 1.59 g (0.0105 mole) of monoacid **7**. After removing the solvent, the ester was obtained as a pale yellow oil (1.64 g, 99%). A gas chromatogram[13] of this product exhibited only one peak. A small sample (150 mg) was distilled through a Hickman still under reduced pressure (2 mm), pot temperature 49°, affording 133 mg of a colorless oil, $n^{23.5}D$ 1.4867.

Anal. Calcd for $C_{10}H_{14}O_2$: C, 72.26; H, 8.49. Found: C, 71.95; H, 8.38.

The infrared spectrum (10% solution in carbon tetrachloride) shows a sharp band at 1732 (ester C=O) and a medium intensity band at 3060 cm^{-1} (*cis*-disubstituted olefin C—H stretch). The nmr spectrum (10% solution in carbon tetrachloride) shows a singlet at τ 4.40, a singlet at 6.37, a quartet centered 7.08, and a complex multiplet in the region from 7.45 to 8.0. The ratios of the corresponding integrated areas closely approximate 2:3:1:8. The proton assignments in this order are vinyl hydrogen, methyl ester hydrogen, the single hydrogen at C_2 (split by *cis* and *trans* hydrogens at C_1 and C_3), and the remaining methylene hydrogens. The coupling constant associated with splitting of the tertiary proton at C_2 is 8 cps.

Diethyl Spiro[3.4]octane-2,2-dicarboxylate (9).—A sample of unsaturated diethyl ester **5a** (0.863 g, 0.00342 mole) was hydrogenated in an ethanolic solution containing palladium on charcoal. After hydrogen uptake ceased, the catalyst was separated, the ethanol was distilled, and the product was finally distilled through a Hickman still affording 0.510 g (59%) of **9**, $n^{24}D$ 1.4530. The sample distilled when the pot temperature reached 110° (1.5 mm) [lit.[8] bp 104–105° (0.2 mm)]. This sample proved to be approximately 98% pure. A pure sample was collected from a vapor phase chromatography column (Apiezon on Chromosorb W). The nmr spectrum of **9** (in dilute CCl_4) shows a quartet and triplet centered at τ 5.84 and 8.76, respectively, attributed to the ester protons and two singlets at 7.61 and 8.42 attributed to the cyclopentane and cyclobutane protons, respectively. The ratios of integrated areas are in accord with these assignments.

Acknowledgments.—The authors gratefully acknowledge the support of this project by the National Science Foundation (GP 4417) and Research Corporation (Frederick Gardner Cotrell Grant). The authors wish to thank Mr. Robert Steed for obtaining many of the spectra.

(12) The diazomethane was generated from Du Pont EXR-101 which contains 70% N,N'-dinitroso-N,N'-dimethylterephthalamide and 30% mineral oil.

(13) The chromatogram was obtained with a 6-ft column packed with silicone oil suspended on Chromosorb W.

Indoles, Benzofurans, Phthalides, and Tolanes *via* Copper(I) Acetylides

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The reaction of cuprous acetylides with *o*-iodoanilines, *o*-halophenols, and *o*-halocarboxylic acids is a general and convenient route to 2-substituted indoles, 2-substituted benzofurans, and 3-alkylidenephthalides. The reaction to produce indoles is markedly dependent upon solvent. *o*-Aminotolanes are smoothly cyclized to indoles by treatment with cuprous iodide in dimethylformanide. *ortho*-Substituted tolanes and polyacetylenes are readily prepared from the acetylides.

We have briefly described the beginnings of a tolane and heterocyclic synthesis based upon the substitution of aryl iodides with cuprous acetylides.[1] We now wish to portray the general scope and utility of these reactions and to correct some errors present in the original studies.

A series of recent reports[2] have delineated the sensitivity of aryl halides toward substitutions with a variety of ligands of cuprous salts (reactions 1 and 2).

$$ArX + CuY \longrightarrow ArY + CuX \quad (1)$$

$$ArX + HY + Cu_2O \longrightarrow ArY + ArH + Ar_2 \quad (2)$$

The ease of replacement of halogen (X) was found to be in the order I > Br > Cl ≫ F, while the efficacy of the cuprous species varied with the nature of the ligand (Y) in the sequence Cl > Br > I > CN > SPh > SCN. A rate expression first order in each reactant was obtained (eq 1). Moreover, as a part of the same study, cuprous acetate was found to dehalogenate reductively *o*-bromonaphthalene (eq 3) in pyridine.

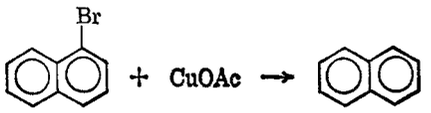
(1) C. E. Castro and R. D. Stephens, *J. Org. Chem.*, **28**, 2163 (1963); R. D. Stephens and C. E. Castro, *ibid.*, **28**, 3313 (1963).

(2) R. G. R. Bacon and H. A. O. Hill, *J. Chem. Soc.*, 1097, 1108, 1117 (1964).

TABLE I
INDOLES

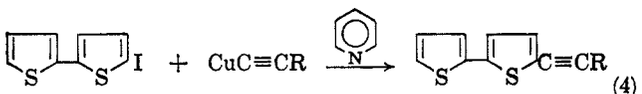
Halide	Acetylide	Solvent	Product	Yield,[a] %	Yield[b] after cyclization, %
o-Iodoaniline	Cuprous phenylacetylide	DMF[c]	2-Phenylindole	89	
o-Iodo-N-ethylaniline	Cuprous phenylacetylide	DMF	1-Ethyl-2-phenylindole	50	
2-Iodo-4-methylaniline	Cuprous phenylacetylide	DMF	5-Methyl-2-phenylindole	90	
4-Hydroxy-2-iodoaniline	Cuprous phenylacetylide	DMF	5-Hydroxy-2-phenylindole	57	
o-Iodoaniline	Cuprous *n*-propylacetylide	Pyridine	2-*n*-Propylindole	70	87
			o-Aminophenyl-*n*-propylacetylene	17	
o-Iodoaniline	Cuprous *n*-butylacetylide	Pyridine	2-*n*-Butylindole[d]	35.4	55
			o-Aminophenyl-*n*-butylacetylene	19.5	
o-Iodoaniline	Cuprous ethylacetylide	Pyridine	2-Ethylindole	12	24
			(*o*-Aminophenylethyl)-acetylene[d]	28	
o-Iodoaniline	Cuprous 2-pyridylacetylide	Pyridine	2-(*o*-Aminophenylethyl)-pyridine	50	
			2-(2′-Pyridyl)indole	0	40
o-Iodo-N-ethylaniline	Cuprous *n*-propylacetylide	Pyridine	1-Ethyl-2-propylindole[d]	50	
			o-Ethylaminophenyl-*n*-propylacetylene	5	

[a] Yield of purified product, based on halide charged. [b] Over-all yield of indole obtained from treatment of mixture with CuI in dimethylformamide based on halide charged. [c] Dimethylformamide. [d] These were mixtures at this stage.



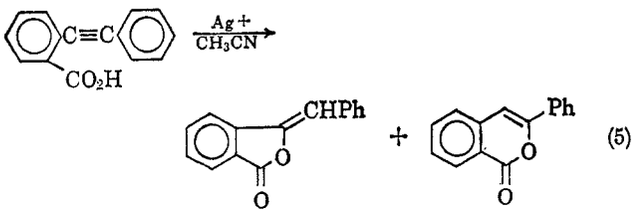
(3)

In reactions analogous to the tolane synthesis previously noted[1] 5-iodo-2,2′-bithienyl has been converted[3] into two alkynyl derivatives (eq 4).



R = CH_2CH_2OH, $CH=CH_2$ (4)

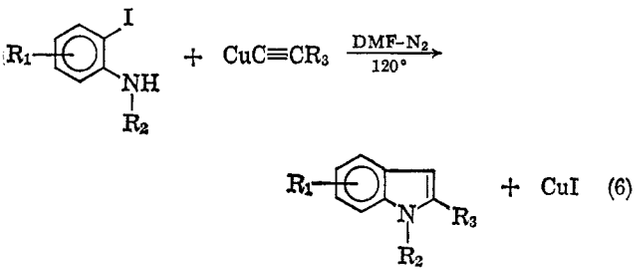
The catalytic effect and directive influence of silver ion upon the cyclization of *o*-carboxytolanes[4] (eq 5) and alkylpropargylidenemalonic acids[5] has recently been examined. The ratio of phthalide to isocoumarin (eq 5) was greatly increased when acetonitrile was employed as the solvent.[4]



(5)

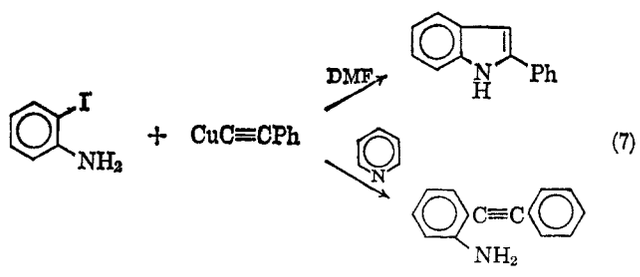
Results

Indoles.—The indole synthesis is typified by eq 6. The results presented in Table I indicate the reaction to be general and competitive with the Fischer synthesis as a route to 2-substituted indoles. It should be emphasized that contrary to earlier reports[1] dimethylformamide and *not* pyridine is the medium of choice for effecting a one-step conversion to indole.



(6)

Indeed, the course of this reaction is markedly influenced by solvent. Thus, the acetylides are but slightly soluble (if at all) in dimethylformamide at room temperature, and the system remains visibly heterogeneous throughout. In this milieu the product is exclusively the indole. In contrast the acetylides are soluble in warm pyridine,[6] and in this solvent, depending upon the nature of the acetylide, the product composition varies from exclusively uncyclized acetylene to mixtures of the acetylene and indole with the latter in preponderance. The course of the reaction of cuprous phenylacetylide with *o*-iodoaniline is illustrative as a case which can be cleanly controlled with solvent to produce either the indole or the tolane selectively (eq 7). Moreover *o*-aminotolane *cannot* be



(7)

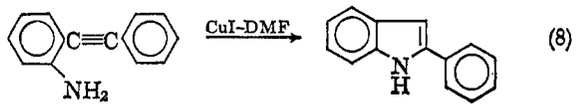
cyclized by either cuprous iodide or cuprous phenylacetylide in pyridine. On the contrary the cyclization is smoothly and quantitatively effected by treatment

(3) R. E. Atkinson, R. E. Curtis, and G. T. Phillips, *Tetrahedron Letters*, No. 43, 3159 (1964).
(4) R. L. Letsinger, E. N. Oftendahl, and J. R. Nazy, *J. Am. Chem. Soc.*, 87, 742 (1965).
(5) C. Belil, J. Pasqual, and F. Servators, *Tetrahedron*, 20, 2701 (1964).
(6) Although in some cases the reaction mixture never became wholly homogeneous.

TABLE II
BENZOFURANS

Halide	Acetylide	Solvent	Product	Yield,[a] %
o-Iodophenol	Cuprous phenylacetylide	DMF	2-Phenylbenzofuran	88
o-Iodophenol	Cuprous *n*-propylacetylide	Pyridine	2-*n*-Propylbenzofuran	60
o-Bromophenol	Cuprous phenylacetylide	Pyridine	2-Phenylbenzofuran	53
2,4-Dibromophenol	Cuprous phenylacetylide	Pyridine	5-Bromo-2-phenylbenzofuran	55
2,4-Dibromophenol	Cuprous *n*-propylacetylide	Pyridine	5-Bromo-2-*n*-propylbenzofuran	40
2,4-Dibromophenol	Cuprous 2-pyridylacetylide	Pyridine	5-Bromo-2-(2-pyridyl)benzofuran	38
o-Bromophenol	Cuprous 2-pyridylacetylide	Pyridine	2-(2-Pyridyl)benzofuran	50
3,5-Diiodo-4-hydroxypyridine	Cuprous phenylacetylide	DMF	7-iodo-2-phenylfuro[3,2-*c*]pyridine	86

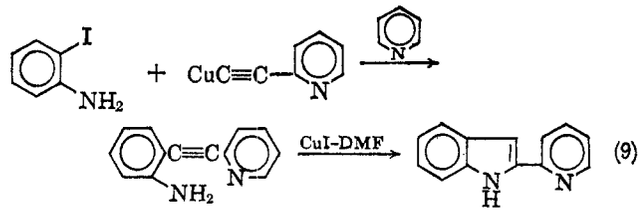
[a] Yield of purified product based on halide charged.



(8)

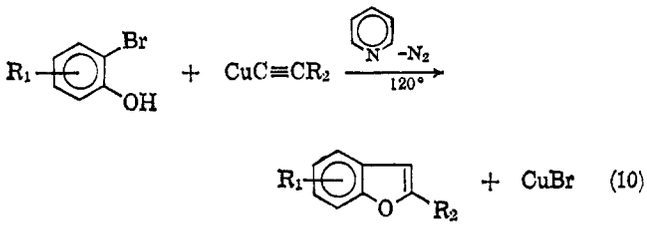
with cuprous iodide in dimethylformamide (eq 8). It does not occur in the absence of copper salt.

On the other hand the initial substitution of iodoanilines is best effected in pyridine. Thus, a 10-hr exposure of *o*-iodoaniline to cuprous 2-pyridylacetylide in dimethylformamide at 125° afforded only starting material. The desired indole could, however, be obtained in the two-step sequence of (eq 9). In general, the two-step sequence is preferred for the preparation of 2-alkylindoles.



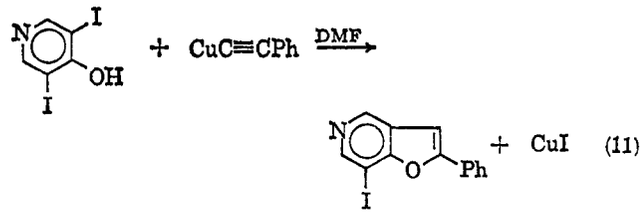
(9)

Benzofurans.—The benzofuran synthesis proceeds smoothly in pyridine[7] (eq 10), and in no case could an uncyclized *o*-hydroxytolane be isolated.



(10)

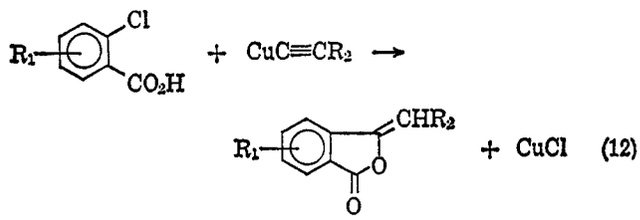
The halogenated phenols react more readily than the corresponding anilines. Hence the more stable bromophenols can conveniently be employed as reactants. The ease of the reaction and heightened lability of the halogen adjacent to the phenolic hydroxyl is manifest in Table II. The reaction of 4-hydroxy-3,4-diiodopyridine with cuprous phenylacetylide (eq 11) is one



(11)

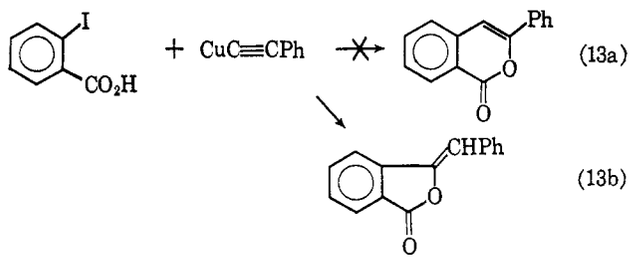
variant suggesting the general utility of these substitutions to build more complex heterocyclic systems.

Phthalides.—Halobenzoic acids comprise a group of the most reactive substrates. Indeed in this series the chlorides are reactive and the reaction can be effected at room temperature. The reaction is typified by eq 12. Both dimethylformamide and pyridine are good solvents.



(12)

We had erroneously characterized[1] the product from *o*-iodobenzoic acid and cuprous phenylacetylide as 3-phenylisocoumarin (eq 13). It is, in fact, the isomeric



(13a)
(13b)

3-benzylidenephthalide as shown by comparison with an authentic sample. Moreover, the reaction is a general preparation of phthalides.[8] The scope of the reaction is indicated in Table III. However, the reaction of *o*-iodobenzoic acid with cuprous *n*-propylacetylide in pyridine or dimethylformamide does result in a mixture of 3-*n*-propylisocoumarin and 3-butylidenephthalide. It is the only case in the present study that results in detectable amounts of isocoumarin.

The high reactivity of the *o*-halo acids prompted an examination of the synthetic potential of an *in situ* generation of the acetylide in this system. This can be smoothly effected by employing cuprous iodide and N-ethylpiperidine as catalysts for the reaction in dimethylformamide. The ease of the transformation is perhaps best illustrated by the preparation of ethyl 3-

(7) Other solvents can be employed but pyridine is the most useful; *cf.* ref 1.

(8) To our regret this error has been propagated at least once; *cf.* R. D. Barry, *Chem. Rev.* **64**, 229 (1964), in which "a promising new isocoumarin synthesis" is noted.

TABLE III
PHTHALIDES

Halide	Acetylide or acetylene	Solvent	*In situ*[a]	Product	Yield,[b] %
o-Iodobenzoic acid	Phenylacetylene	DMF	Yes	3-Benzylidenephthalide	90
o-Bromobenzoic acid	Phenylacetylene	DMF	Yes	3-Benzylidenephthalide	53
o-Chlorobenzoic acid	Phenylacetylene	DMF	Yes	3-Benzylidenephthalide	39
o-Chlorobenzoic acid	Cuprous phenylacetylide	Pyridine	No	3-Benzylidenephthalide	65
2,4-Dichlorobenzoic acid	Cuprous phenylacetylide	Pyridine	No	3-Benzylidene-5-chlorophthalide	69
o-Iodobenzoic acid	Ethyl propiolate	DMF	Yes[c]	Ethyl 3-phthalylideneacetate	39
o-Bromobenzoic acid	Ethyl propiolate	DMF	Yes[c]	Ethyl 3-phthalylideneacetate	15
o-Iodobenzoic acid	Propargyl alcohol	DMF	Yes[c]	3-Phthalylideneethanol	6
o-Iodobenzoic acid	Cuprous *n*-propylacetylide	Pyridine	No	3-*n*-Propylisocoumarin	40
				3-Butylidenephthalide	22

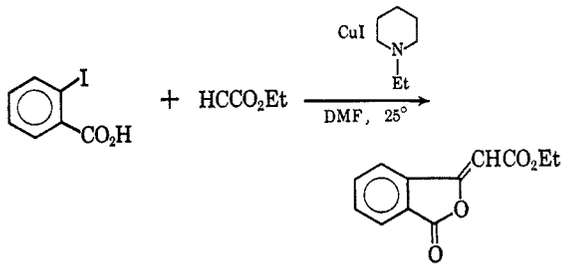
[a] With cuprous iodide and N-ethylpiperidene as catalysts. [b] Yield of purified material based on halide charged. [c] Reactions run at room temperature.

TABLE IV
TOLANES

Halide	Acetylide	Solvent	Product	Yield,[a] %
o-Diiodobenzene	Cuprous phenylacetylide	Pyridine	*o*-Bis(phenylethynyl)benzene	61
m-Diiodobenzene	Cuprous phenylacetylide	Pyridine	*m*-Bis(phenylethynyl)benzene	42
p-Diiodobenzene	Cuprous phenylacetylide	Pyridine	*p*-Bis(phenylethynyl)benzene	45
o-Iodoaniline	Cuprous phenylacetylide	Pyridine	*o*-Aminotolane	59
o-Iodo-N-ethylaniline	Cuprous phenylacetylide	Pyridine	*o*-Ethylaminotolane	5[b]
o-Iodobenzamide	Cuprous phenylacetylide	Pyridine	*o*-Carboxamidotolane	47
o-Iodobenzamide	Cuprous *n*-propylacetylide	Pyridine	*o*-Carboxamidophenyl-*n*-propylacetylene	50
o-Iodobenzyl alcohol	Cuprous phenylacetylide	Pyridine	*o*-Hydroxymethyltolane	50
3-Iodopyridine	Cuprous phenylacetylide	Pyridine	2-Phenylethynylpyridine	47
2-Iodopyridine	Cuprous phenylacetylide	Pyridine	2-Phenylethynylpyridine	25
Picryl chloride	Cuprous phenylacetylide	DMF	2,4,6-Trinitrophenylphenylacetylene	34
o-Iodoaniline	Cuprous 2-pyridylacetylide	Pyridine	2-(*o*-Aminophenylethynyl)pyridine	50
2-Iodo-4-methylaniline	Cuprous phenylacetylide	Pyridine	2-Amino-5-methylphenylphenylacetylene	92

[a] Yield of purified product based on halide charged. [b] See Table I, 1-ethyl-2-phenylindole is the major product.

phthalylideneacetate by simply mixing the reactants and stirring under nitrogen at room temperature (eq 14). It should be noted that although a 50% yield

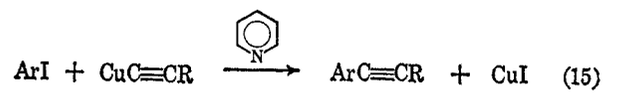


(14)

of 3-benzylidenephthalide could be obtained from *o*-bromobenzoic acid under *in situ* conditions at 130° for 7 hr, *p*-bromobenzoic acid was inert under these conditions. The enhanced reactivity of the halogen *ortho* to the carboxyl is also apparent in the good yield of 3-benzylidene-5-chlorophthalide from 2,4-dichlorobenzoic acid.

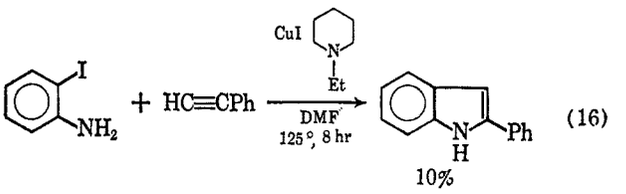
Tolanes.—The general character of the tolane synthesis has been described.[1] We now wish to report the versatility of the reaction to prepare substituted acetylenes, even in the *ortho* position, and to point up the ease of polycondensations.[9] The reactions are exemplified by eq 15 and the results are presented in Table IV.

(9) The selective substitution of one halogen in an aromatic polyhalide and a polycondensation in the biphenyl system have been observed under our conditions: private communication from Professor R. E. Dessey.



(15)

In Situ **Generation of the Acetylide.**—The catalytic conditions successfully employed for the phthalide synthesis are not readily transposed as a preparative procedure to the other syntheses portrayed herein. The poorer yields with this recipe (eq 16–19) are



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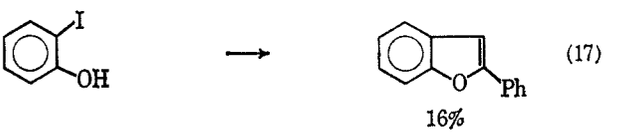

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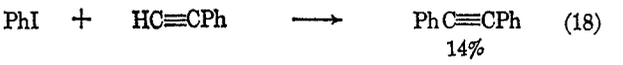

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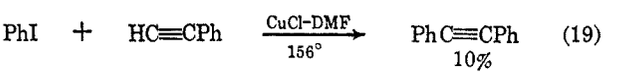


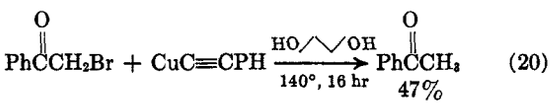
(19)

to be compared with the data in Tables I, II, and IV. Moreover, it was found that N-ethylpiperidine decreased the yield of 2-phenylbenzofuran from preformed cuprous phenylacetylide and *o*-iodophenol to

41%. This is to be compared with an 88% yield of product in this solvent in the absence of the tertiary base.

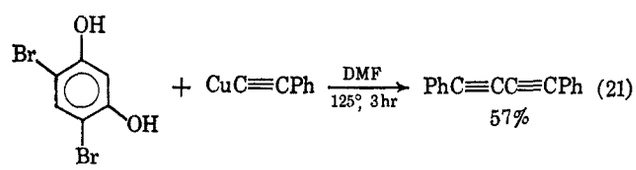
Side Reactions.—The processes noted in the foregoing sections proceed cleanly to the products indicated. The reactions shown below represent potential side reactions that may occur when a relatively inactive substrate is exposed to acetylide. In another sense they represent unsuccessful condensations. Illustrative cases are presented.

Reduction.—The attempted condensation of phenacyl bromide with cuprous phenylacetylide in a variety of solvents afforded mainly intractable tars. With ethylene glycol as the solvent acetophenone was obtained (eq 20). This reduction with cuprous acetylide is reminiscent of the reduction of this halide with Cr(II) and other low valent species.[10] Similarly, in addition to tar, α-iodo-β-naphthol provided a 2% yield of β-naphthol when exposed to cuprous phenylacetylide in dimethylformamide at 152°.

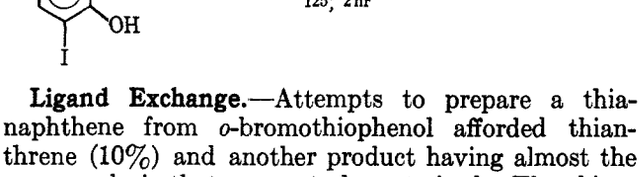


(20)

Coupling.—Unreactive phenols promote the oxidative coupling of the acetylide. Thus, in addition to tar, α-bromo-β-naphthol and cuprous phenylacetylide in dimethylformamide yielded small amounts (5%) of 1,4-diphenylbutadiyne.[11] Similarly reactions with 4,6-dibromoresorcinol yielded the diacetylene in substantial yield eq 21. Moreover, a very small amount of the diacetylene was obtained when resorcinol was employed as the "substrate." With 4,6-diiodoresorcinol in acetic acid the corresponding butenyne was produced in addition to tars (eq 22). Similar results were obtained with α-bromo-β-naphthol in acetic acid.[12]

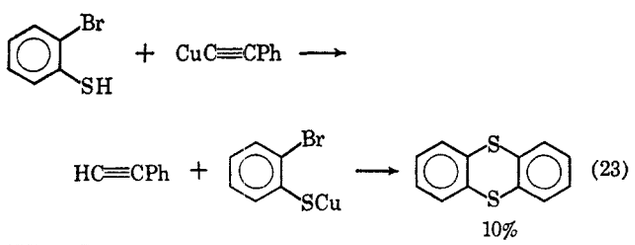


(21)



(22)

Ligand Exchange.—Attempts to prepare a thianaphthene from *o*-bromothiophenol afforded thianthrene (10%) and another product having almost the same analysis that was not characterized. The thianthrene presumably arises *via* eq 23.



(23)

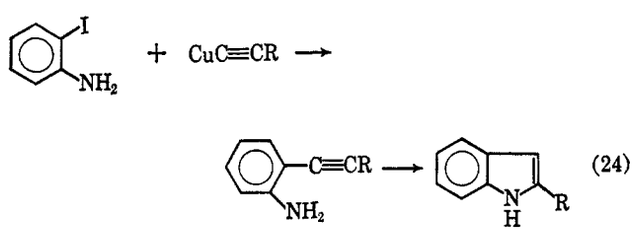
(10) C. E. Castro and W. C. Kray, Jr., *J. Am. Chem. Soc.*, **85**, 2768 (1963). The reduction can also be effected with cuprous bromide in DMF–H_2O.

Discussion

The reaction of cuprous acetylides with appropriately substituted aryl halides in a nitrogen atmosphere provides an exceedingly facile and general synthesis of 2-substituted indoles, 2-substituted benzofurans, 3-alkylidenephthalides, and tolanes in good yield.

The reactivity of the halides (I > Br > Cl) accords with that observed for substitution by other ligands[2] of Cu(I), and the effectiveness of an *ortho*-nucleophilic substituent to promote the reaction is in the order $CO_2H > OH > NH_2$. Thus the phthalide synthesis is the most rapid.

Although the evidence at hand supports a two-step sequence only for the indole synthesis (eq 24) this is also a reasonable path to the benzofurans and phthalides. The decreased efficiency of the benzofuran synthesis in the presence of N-ethylpiperidine and the marked solvent effects observed in the indole synthesis suggest that strong coordination of copper can mask the ability of the metal to effect the initial alkylation or to coordinate with the acetylene in the way that is necessary for cyclization.



(24)

An extension of the scope of these kinds of transformations to other heterocyclic systems and studies of the mechanism of the substitution and cyclization processes are underway.

Experimental Section

The Acetylides.—The cuprous salts of phenyl-, *n*-propyl-, ethyl-, and butylacetylene were obtained by treatment of an aqueous ammoniacal solution of cuprous iodide with an ethanolic solution of the acetylene in the manner previously described.[1] An alternate procedure which provided a purer product utilized hydroxylamine as a reductant for Cu(II). It is described for cuprous phenylacetylide.

A mixture of 25.0 g (0.10 mole) of $CuSO_4 \cdot 5H_2O$ and 100 ml of 28% ammonium hydroxide was stirred magnetically for a short time in a 2-l. erlenmeyer flask under a nitrogen sweep. After the addition of 400 ml of water, 13.9 g (0.20 mole) of solid hydroxylamine hydrochloride was added. The dark blue solution turned lighter and was cooled. After approximately 5 min, 10.2 g (0.10 mole) of phenylacetylene in 500 ml of ethanol was added. The canary yellow acetylide formed immediately. The precipitate was filtered off and washed successively five times each with 100-ml portions of water, ethanol, and diethyl ether. The solid was dried for 4 hr at 65° *in vacuo* in a rotary evaporator. The process yielded 16.4 g (0.10 mole, 100%) of cuprous phenylacetylide. Orange cuprous 2-pyridylacetylide was obtained in 51% yield by this procedure.

Cuprous carbethoxyacetylide and cuprous hydroxymethylacetylide were generated *in situ* by the reaction of N-ethylpiperidine and cuprous iodide with the corresponding acetylenes in dimethylformamide. This procedure is given in the general examples of the phthalide synthesis described below.

(11) The product can be obtained from the acetylide in most solvents if oxygen is not excluded.

(12) Presumably 1,4-diphenylbutadiyne is reduced by Cu(I) to the enyne in this solvent. This conversion has been reported long ago to occur upon prolonged reflux of the acetylide in acetic acid exposed to air.

The Substitutions.—All reactions were carried out in a nitrogen atmosphere. Illustrative examples are presented for each kind of transformation.

Procedure A. 5-Methyl-2-phenylindole.—To a 200-ml, three-necked flask equipped with nitrogen inlet, a reflux condensor connected to a mercury trap, and a magnetic stirring bar was added 1.86 g (0.011 mole) of cuprous phenylacetylide and 80 ml of dimethylformamide (DMF). The flask and contents were thoroughly flushed with nitrogen with stirring. Under nitrogen 2.56 g (0.011 mole) of 2-iodo-4-methylaniline in 20 ml of DMF was added. The contents were stirred and warmed at 120° in an oil bath for 22 hr. The dark reaction mixture was filtered and the filtrate was concentrated to dryness *in vacuo* in a rotary evaporator. The resulting residue was taken up in chloroform, filtered, added to petroleum ether (bp 60–70°), and concentrated. The concentrate crystallized and the substance was recrystallized from chloroform–petroleum ether to yield 2.04 g (0.099 mole, 90%) of 5-methyl-2-phenylindole having mp 214–214.5° (lit.[13] 213°). A pine splint test was positive. The infrared spectrum was similar to that of 2-phenylindole and showed an NH singlet at 3460 cm^{-1}.

Procedure B. 2-Butylindole.—In similar fashion 10.3 g (0.047 mole) of *o*-iodoaniline and 6.88 g (0.047 mole) of cuprous *n*-butylacetylide were warmed in 155 ml of pyridine at 120° for 8 hr. The cooled reaction mixture was filtered and concentrated *in vacuo*. The concentrate was treated with 200 ml of water and 200 ml of ether and vigorously shaken. The precipitated cuprous iodide was filtered off and the filter cake was repeatedly washed with ether. The aqueous phase was extracted three times with 100-ml portions of ether. Ether washings and extracts were combined and washed successively three times each with cold 1% HCl, 5% sodium bicarbonate, and water, and dried over magnesium sulfate. The solution was concentrated and distilled through a small Vigreux column. The fractions given in Table V were obtained. Analysis of 2-*n*-butylindole and *o*-

TABLE V

Fraction	Bp, °C (mm)	Wt, g	% indole	% acetylene
I	44–75 (0.1)	Rejected		
II	75–80 (0.1)	0.57	38	62
III	80–90 (0.1)	0.57	40	60
IV	97–97.5 (0.1)	3.33	73	27

aminophenyl-*n*-butylacetylene was performed on a 6-ft Dow Corning gas chromatographic column at 200°. The indole and acetylene emerged at 17 and 23 min, respectively. The over-all yield of acetylene and indole was 19.5 and 35.4%. Authentic samples were trapped from the column that were pure, by infrared analysis. Thus, the indole possessed a spectrum similar to 2-*n*-propylindole and showed a singlet NH at 3390 cm^{-1} while the spectrum of the acetylene contained a doublet at 3340 and 3470 cm^{-1} (NH_2) and typical bands of aromatic *ortho* disubstitution. The C≡C bond was not visible. The isomeric mixture from fraction III was submitted for analysis.

Anal. Calcd for $C_{12}H_{15}N$: C, 83.19, H, 8.73; N, 8.08. Found: C, 83.14; H, 8.80; N, 8.14.

The mixture (2 g) from fraction IV was treated with 0.57 g of CuI in 35 ml of DMF for 7 hr under nitrogen. The mixture was worked up as above and 0.19 g of 2-*n*-butylindole was distilled at 98–100° (0.1 mm), mp 28–29.5°. The substance showed the same singlet NH in the infrared spectrum and only one peak when gas chromatographed.

2-Phenylindole.—A mixture of 4.0 g (0.0175 mole) of *o*-iodoaniline and 3.0 g (0.0182 mole) of cuprous phenylacetylide was warmed and stirred in 100 ml of DMF at 175°. After concentration, the residue was treated with water and ether and worked up in the manner described in procedure A. The washed and dried ethanol concentrate afforded a brownish solid that was recrystallized from petroleum ether to yield 3.0 g (0.0155 mole, 89% of 2-phenylindole. The white plates had a melting point and mixture melting point with an authentic sample of 189°. The infrared spectrum was identical with that of an authentic sample.

Procedure C. Cyclization of *o*-Aminotolane.—The tolane (2.0 g, 0.0104 mole) was added to a mixture of 1.0 g of cuprous iodide (0.0053 mole) in 75 ml of DMF and warmed for 8 hr at 110° with stirring. Work-up as above yielded 1.90 g (95%) of phenylindole. The same treatment in pyridine resulted in the isolation of 1.85 g (93%) of starting *o*-aminotolane.

1-Ethyl-2-phenylindole.—*o*-Iodo-*n*-ethylaniline (0.71 g, 0.0023 mole) and cuprous phenylacetylide (0.54 g, 0.033 mole) underwent reaction in 20 ml of DMF as in procedure A. Recrystallization from petroleum ether afforded 0.39 g (50%) of 1-ethyl-2-phenylindole with mp 84–85.5° (lit.[14] 80°). No NH band was visible in the infrared spectrum.

Anal. Calcd for $C_{16}H_{15}N$: C, 86.90; H, 6.78. Found: C, 87.05; H, 6.81.

5-Hydroxy-2-phenylindole.—By procedure A, 2.35 g (0.01 mole) of 4-amino-3-iodophenol and 1.65 g (0.01 mole) of cuprous phenylacetylide in 50 ml of DMF afforded 1.2 g (0.00575 mole, 57%) of benzene-recrystallized 5-hydroxy-2-phenylindole. The bluish crystals had mp 236–239 (lit.[15] 238°). Infrared spectrum analysis showed a singlet NH band at 3410 cm^{-1}.

2-(2′-Pyridyl)indole.—2-(*o*-Aminophenylethynyl)pyridine (0.42 g, 0.0022 mole) was cyclized according to procedure C with 0.25 g (0.0013 mole) of cuprous iodide in 25 ml of DMF. The product was recrystallized from benzene–petroleum ether to yield 0.27 g (0.0014 mole, 64%) of 2-(2′-pyridyl)indole with mp 153–154° (lit.[16] 154°). A pine splint test was positive.

2-*n*-Propylindole.—*o*-Iodoaniline (7.55 g, 0.0344 mole) and cuprous *n*-propylacetylide (4.50 g, 0.0346 mole) in 100 ml of pyridine yielded, according to procedure B, 4.9 g (0.0308 mole, 89%) of a mixture of 2-*n*-propylindole (80%) and *o*-aminophenylpropylacetylene having bp 93° (0.3 mm). The mixture was cyclized *via* procedure C to yield pure 2-*n*-propylindole; infrared spectrum showed a NH singlet at 3390 cm^{-1}.

Anal. Calcd for $C_{11}H_{13}N$: C, 83.02; H, 8.18; N, 8.80. Found: C, 82.90; H, 8.18; N, 8.80.

1-Ethyl-2-*n*-propylindole.—According to procedure A, *o*-iodoaniline (6.17 g, 0.0246 mole) and cuprous *n*-propylacetylide (3.34 g, 0.0256 mole) in 75 ml of pyridine yielded 2.8 g of a distilled oil which showed a very weak NH (the acetylene impurity) in the infrared spectrum. Rather than cyclizing, *via* procedure C, the oil was taken up in ether and again washed repeatedly with cold dilute HCl, sodium bicarbonate, and water. The dried, concentrated ethanol residue was redistilled at 92–95° (0.1–0.2 mm). Although diminished, a small NH band was still present in the impure sample. It should be noted that the condensation did not occur in DMF.

Anal. Calcd for $C_{13}H_{17}N$: C, 82.23; H, 9.78. Found: C, 81.76; H, 9.11.

2-Ethylindole.—*o*-Iodoaniline (5.48 g, 0.025 mole) and cuprous ethylacetylide in 100 ml of pyridine yielded, by procedure B, 1.81 g of product with boiling range 75–90° (0.1 mm). The mixture contained 25% indole and 56% *o*-aminophenylbutylacetylene. The yield of the two products was 12.4 and 27.6%, respectively.

A total of 2.89 g of the indole–acetylene mixture was cyclized according to procedure C and provided 1.8 g (66%) of pure 2-ethylindole with bp 94–96° (0.2 mm) and mp 45.5–46° (lit.[17] 46°).

Anal. Calcd for $C_{10}H_{11}N$: C, 82.71; H, 7.64. Found: C, 82.44; H, 7.54.

2-Phenylbenzofuran.—*o*-Iodophenol (4.03 g, 0.0183 mole) and cuprous phenylacetylide in 100 ml of DMF or pyridine (*cf.* ref 1) according to procedure A afforded 3.4 g (0.0175 mole, 85%) of petroleum ether recrystallized 2-phenylbenzofuran, mp and mmp 120–121°. The infrared spectrum was identical with that of an authentic sample. Starting with *o*-bromophenol in pyridine the yield was 56%. *o*-Chlorophenol was inert under these conditions. In another experiment, the iodide was treated as above in DMF except that 2 moles of N-ethylpiperidine/mole of acetylide were added and the yield was decreased to 41%.

An *in situ* generation of the acetylide (procedure D), described below for 3-benzylidenephthalide, starting with *o*-iodophenol yielded 16% of 2-phenylbenzofuran. For all benzofuran preparations in this work the infrared spectrum of the product showed no trace of C≡C or OH.

2-*n*-Propylbenzofuran.—*o*-Iodophenol (4.03 g, 0.0183 mole) and cuprous *n*-propylacetylide (2.40 g, 0.0184 mole) in 100 ml of

(13) A. Bischeler, *Ber.*, **25**, 2874 (1892).

(14) J. Cul Mann, *ibid.*, **21**, 2596 (1888).

(15) H. J. Teuber and G. Steiger, *ibid.*, **89**, 489 (1956).

(16) T. Sugasawa, M. Terashima, and K. Kanaoka, *Pharm. Bull* (Tokyo), **4**, 16 (1956).

(17) J. R. Catch, D. F. Elliot, D. H. Hey, and E. R. H. Jones, *J. Chem. Soc.*, 272 (1948).

pyridine, *via* procedure A, yielded 1.2 g (42%) of 2-*n*-propylbenzofuran with bp 61–62 (0.75 mm) (lit.[18] 107–110°, 12.5 m).

Anal. Calcd for $C_{11}H_{12}O$: C, 82.51; H, 7.50. Found: C, 82.51; H, 7.53.

5-Bromo-2-phenylbenzofuran.—2,4-Dibromophenol (2.5 g, 0.01 mole) and cuprous phenylacetylide (1.65 g, 0.01 mole) in 60 ml of pyridine afforded, *via* procedure A, 1.50 g (55%) of methanol-recrystallized 5-bromo-2-phenylbenzofuran with mp 158–159 (lit.[19] 148). A twice-recrystallized sample (mp 158–159°) was analyzed.

Anal. Calcd for $C_{14}H_9BrO$: C, 61.56; H, 3.32; Br, 29.26. Found: C, 61.51; H, 3.40; Br, 29.30.

2-(2′-Pyridyl)benzofuran.—*o*-Bromophenol (1.73 g, 0.01 mole) and cuprous 2-pyridylacetylide (1.66 g, 0.01 mole) in 50 ml of DMF yielded, *via* procedure A, 0.98 g (0.005 mole, 50%) of 2-(2′pyridyl)benzofuran with mp 82–83°.

Anal. Calcd for $C_{13}H_{19}NO$: C, 79.97; H, 4.64; N, 7.17. Found: C, 80.02; H, 4.74; N, 7.13.

7-Iodo-2-phenylfuro[3,2-*c*]pyridine.—3,5-Diiodo-4-pyridinol (3.47 g, 0.01 mole) and cuprous phenylacetylide (4.11 g, 0.025 mole) in 130 ml of DMF afforded a black intractable tar upon concentration of the filtered reaction mixture. The tar complex was dissolved in 28% aqueous ammonia and extracted three times with ether. The ether extracts were washed with water and dried over magnesium sulfate. The concentrated ether solution crystallized, and the solid was recrystallized (Norit) from aqueous ethanol to yield 2.76 g (0.086 mole, 86%) of 7-iodo-2-phenylfuro-[3,2-*c*]pyridine with mp 134–135°. The infrared spectrum *did not* show any adsorption for NH, OH, C=O, or C≡C.

Anal. Calcd for $C_{13}H_{16}INO$: C, 48.62; H, 2.51; I, 39.52; N, 4.36. Found: C, 48.97; H, 2.92; I, 39.37; N, 4.58.

When the reaction was run in pyridine for 6 hr at room temperature a 25% yield of this substance was obtained.

5-Bromo-2-(2′-pyridyl)benzofuran.—2,4-Dibromophenol (5.04 g, 0.02 mole) and cuprous 2-pyridylacetylide (3.31 g, 0.02 mole) in 100 ml of pyridine in the manner described immediately above afforded 2.06 g (0.0075 mole, 38%) of petroleum ether recrystallized 5-bromo-2-(2′-pyridyl)benzofuran with mp 167–168.

Anal. Calcd for $C_{15}H_8BrNO$: C, 56.96; Br, 29.15; H, 2.94; N, 5.11. Found: C, 57.05; H, 3.23; Br, 29.30; N, 4.93.

5-Bromo-2-*n*-propylbenzofuran.—2,4-Dibromophenol (5.04 g, 0.02 mole) and cuprous *n*-propylacetylide (2.61 g, 0.02 mole) in 100 ml of pyridine *via* procedure A yielded 1.98 g (0.008 mole, 40%) of 5-bromo-2-*n*-propylbenzofuran with bp 102–103 (2.5 mm). The nmr spectrum showed absorptions at δ 7.18 (singlet, 1 H), 6.88 (singlet 2 H), 5.75 (singlet, 1 H), 2.31 (triplet, 2 H), 1.37 (multiplet, 2 H), and 1.66 triplet, 3 H).

Anal. Calcd for $C_{11}H_{11}BrO$: C, 55.25; H, 4.64; Br, 33.42. Found: C, 54.55; H, 4.58; Br, 33.50.

Procedure D. 3-Benzylidenephthalide.—Phenylacetylene (1.86 g, 0.0182 mole) and N-ethylpiperidine (4.12 g, 0.0364 mole) in 80 ml of DMF were stirred and thoroughly purged with nitrogen for 0.5 hr. Finely powdered cuprous iodide (3.47 g, 0.0182 mole) was added under a nitrogen sweep. The bright yellow copper complex immediately precipitated. To the mixture was added 4.50 g (0.0204 mole) of *o*-iodobenzoic acid in 20 ml of DMF. The mixture was warmed at 125° for 6 hr. During this time the yellow solid dissolved and the reaction mixture turned brown. The cooled solution was filtered, the filter cake was washed with DMF, and the filtrates were combined and concentrated *in vacuo* to a volume of *ca.* 10 ml. The residue was treated with 100 ml of water and 100 ml of ether and vigorously shaken. The aqueous phase was extracted three times with 50-ml portions of ether. The ether extracts were combined, washed with dilute sodium bicarboate and water, and dried over magnesium sulfate. The concentrated ether solution crystallized to yield 3.60 g (0.0163 mole, 90%) of 3-benzylidenephthalide with mp 92–93°. The substance was recrystallized from petroleum ether and had mp and mmp 98–99.5.

The infrared spectrum was identical with an authentic sample's. A mixture melting point of this substance with authentic 3-phenylisocoumarin was depressed to 71–84°. The yield of recrystallized phthalide with *o*-bromobenzoic acid and *o*-chlorobenzoic acid in this procedure was 53 and 39%, respectively. With the iodide, and pyridine as the solvent, the yield was 14%.

The reaction *o*-chlorobenzoic acid with preformed cuprous phenylacetylide in pyridine afforded a 68% yield of the phthalide.

Ethyl 3-Phthalylideneacetate.—Ethyl propiolate (2.94 g, 0.03 mole), cuprous iodide (5.74 g, 0.03 mole), N-ethylpiperidine (3.40 g, 0.03 mole), and *o*-iodobenzoic acid (7.44 g, 0.03 mole) in 150 ml of DMF, stirred for 21 hr at room temperature *via* procedure D, yielded 3.9 g (0.0117 mole, 39%) of benzene–petroleum ether recrystallized ester with mp 134–135° (lit.[20] 132–134°). The infrared showed phthalide (1700 cm^{-1}) and ester (1695 cm^{-1}) carbonyls; nmr spectrum: δ 1.27 (triplet, 3 H), 4.43 (quadruplet, 2 H), 5.94 (singlet, 1 H), and 7.83 (multiplet, 4 H).

Anal. Calcd for $C_{12}H_{10}O_4$: C, 66.05; H, 4.62. Found: C, 66.50; H, 4.70.

Beginning with *o*-bromobenzoic acid a 15% yield of the phthalide ester was obtained.

3-Phthalylideneethanol.—Propargyl alcohol (1.68 g, 0.03 mole), cuprous iodide (5.72 g, 0.03 mole), N-ethylpiperidine (3.96 g, 0.035 mole), and *o*-iodobenzoic acid (7.44 g, 0.03 mole) in 130 ml of DMF for 96 hr at room temperature *via* procedure D afforded a brown intractable glass from which 0.03 g (6%) of 3-phthalylideneethanol, mp 96.5–98.5, could be extracted with benzene–petroleum ether: infrared spectrum: C=O at 1780 cm^{-1}; nmr spectrum: δ 2.17 (singlet, 1 H), 4.65 (doublet, 2 H), 5.88 (triplet, 1 H), and 7.72 (multiplet, 4 H).

Anal. Calcd for $C_{10}H_8O_3$: C, 68.17; H, 4.57. Found: C, 68.25; H, 4.52.

5-Chloro-3-benzylidenephthalide.—2,4-Dichlorobenzoic acid (3.90 g, 0.02 mole) and cuprous phenylacetylide (3.29 g, 0.02 mole) in 110 ml of pyridine for 3 hr at 125° *via* procedure A afforded 2.65 g (0.0116 mole, 69%) of benzene–cyclohexane recrystallized 5-chloro-3-benzylidenephthalide with mp 189.5–189.9°; infrared spectrum: C=O at 1775 cm^{-1}.

Anal. Calcd for $C_{15}H_9ClO_2$: C, 70.18; H, 3.53; Cl, 13.81. Found: C, 70.16; H, 3.65; Cl, 13.79.

3-*n*-Butylidenephthalide and 3-*n*-Propylisocoumarin.—*o*-Iodobenzoic acid (6.20 g, 0.025 mole) and cuprous phenylacetylide (3.47 g, 0.0266 mole) in 120 ml of pyridine *via* procedure A yielded 3.0 g (64%) of a mixture of the phthalide and isocoumarin: infrared spectrum: C=O at 1773 (phthalide) and 1720 cm^{-1} (isocoumarin). The isomer mixture was not resolved by gas chromatography. A distribution of 61.5% isocoumarin and 38.5% phthalide was determined from the ratio of areas of the vinyl proton at δ 5.58 (triplet) for the phthalide and 6.2 (singlet) for the isocoumarin in the nmr spectrum of the isomer mixture.

Anal. Calcd for $C_{12}H_{12}O_2$: C, 76.52; H, 6.43. Found: C, 76.50; H, 6.48.

***o*-Bis(phenylethynyl)benzene.**—*o*-Diiodobenzene (1.46 g, 0.044 mole) and cuprous phenylacetylide (1.52 g, 0.0092 mole) in 60 ml of pyridine at 125° for 16.5 hr *via* procedure A yielded 0.75 g (61.5%) of petroleum ether recrystallized diacetylene with mp 47–48°; infrared spectrum: C≡C at 2200 cm^{-1}.

Anal. Calcd for $C_{22}H_{14}$: C, 95.00; H, 5.00. Found: C, 94.65; H, 5.24.

***m*-Bis(phenylethynyl)benzene.**—*m*-Diiodobenzene (1.27 g, 0.0038 mole) and cuprous phenylacetylide (1.32 g, 0.008 mole) in 50 ml of pyridine at 120° for 15 hr *via* procedure A yielded 0.44 g (42%) of petroleum ether recrystallized diacetylene with mp 114–115°; infrared spectrum showed no C≡C.

Anal. Calcd for $C_{22}H_{14}$: C, 95.00; H, 5.00. Found: C, 94.96; H, 5.02.

***p*-Bis(phenylethynyl)benzene.**—*p*-Diiodobenzene (3.30 g, 0.01 mole) and cuprous phenylacetylide (3.45 g, 0.021 mole) in 100 ml of pyridine for 16 hr at 120° afforded *via* procedure A 1.25 g (45%) of diacetylene with mp 178–179° (lit.[21] 181–182°); infrared spectrum: weak C≡C at 2200 cm^{-1}.

Anal. Calcd for $C_{14}H_{22}$: C, 95.00; H, 5.00. Found: C, 95.07; H, 4.92.

***o*-Aminotolane.**—*o*-Iodoaniline (4.0 g, 0.0175 mole) and cuprous phenylacetylide (3.0 g, 0.0182 mole) in 100 ml of pyridine for 8 hr at 120° *via* procedure A yielded 2.0 g (59%) of petroleum ether recrystallized tolane with mp 91–92° (lit.[22] 89–90°); infrared spectrum: C≡C at 2250 and NH_2 at 3500 and 3650 cm^{-1}.

Anal. Calcd for $C_{14}H_{11}N$: C, 87.05; H, 5.70; N, 7.26. Found: C, 86.73; H, 5.77; N, 7.66.

***o*-Ethylaminotolane.**—*o*-Iodo-N-ethylaniline (1.24 g, 0.005 mole) and cuprous phenylacetylide (0.85 g, 0.0052 mole) in 35

(18) H. Normant, *Ann. Chem.*, **17**, 335 (1942).
(19) R. Stoermer and M. Reuter, *Ber.*, **36**, 3982 (1903).
(20) S. Gabriel, L. Kornfeld, and C. Grunnert, *ibid.*, **57**, 305 (1924).
(21) W. Reid and A. Urschel, *ibid.*, **91**, 2459 (1958).
(22) K. Shofield and T. Swain, *J. Chem. Soc.*, 2397 (1949).

ml of pyridine for 8 hr at 120° afforded *via* procedure A 0.55 g (50%) of a dark oil which could not be induced to crystallize. The crude product was not purified further; infrared spectrum: C≡C at 2190 and a secondary amine at 3390 cm^{-1}.

o-Carboxamidotolane.—*o*-Iodobenzamide (4.23 g, 0.018 mole) and cuprous phenylacetylide (2.77 g, 0.0182 mole) in 100 ml of pyridine for 8 hr at 120° *via* procedure A afforded 1.85 g (47%) of chloroform-recrystallized tolane with mp 156–157°; infrared spectrum: C≡C at 2210, C=O at 1680, and NH_2 at 3350–3450 cm^{-1}.

Anal. Calcd for $C_{15}H_{11}NO$; C, 81.50; H, 4.97. Found: C, 81.09; H, 5.18. The same material was obtained with DMF as the solvent.

o-Hydroxymethyltolane.—*o*-Iodobenzyl alcohol and 2.16 g (0.0121 mole) of cuprous phenylacetylide in 75 ml of pyridine for 7 hr at 120° afforded *via* procedure A 1.25 g (50%) of petroleum ether recrystallized *o*-hydroxymethyltolane with mp 69–71°. Two additional recrystallizations brought the melting point to 71–71.5°; infrared spectrum: C≡C at 2200 and OH at 3570 and 3700–3500 cm^{-1}.

Anal. Calcd for $C_{15}H_{12}O$: C, 86.51; H, 5.81. Found: C, 86.52; H, 5.74.

3-Phenylethynylpyridine.—3-Iodopyridine (5.13 g, 0.025 mole) and cuprous phenylacetylide (4.67 g, 0.028 mole) in 130 ml of pyridine for 9 hr at 120° afforded, *via* procedure B an oil with bp 94–97° (0.1 mm) which solidified and was recrystallized from petroleum ether to give 2.07 g (47%) of the acetylene with mp 47–48.5; infrared spectrum: C≡C at 2200 cm^{-1}.

Anal. Calcd for $C_{13}H_9N$: C, 87.12; H, 5.06. Found: C, 87.07; H, 5.37.

(2,4,6-Trinitrophenyl)phenylacetylene.—Picryl chloride (2.47 g, 0.01 mole) and cuprous phenylacetylide (1.65 g, 0.01 mole) in 50 ml of DMF for 3 hr at 100° yielded *via* procedure A 0.90 g (0.0034 mole, 34%) of aqueous ethanol-recrystallized red acetylene with mp 205.5–206.5; infrared spectrum: C≡C at 2200 and NO_2 at 1540 and 1335 cm^{-1}; nmr: δ 6.74 (singlet, 5 H) and 8.31 (singlet, 2 H).

Anal. Calcd for $C_{14}H_7N_3O_6$: C, 53.68; H, 2.25; N, 13.45. Found: C, 53.73; H, 2.60; N, 13.06.

2-Phenylethynylpyridine.—2-Iodopyridine (2.05 g, 0.01 mole) and cuprous phenylacetylide (1.65 g, 0.01 mole) in 50 ml of DMF at 120° for 18 hr yielded *via* procedure A 0.45 g (0.0025 mole, 25%) of the acetylene with bp 134° (0.2 mm) [lit.[23] 148–50 (1.0 mm)]. The clear liquid was soluble in dilute HCl; infrared spectrum: C=C at 2205 cm^{-1}.

2-(*o*-Aminophenylethynyl)pyridine.—*o*-Iodoaniline (2.19 g, 0.01 mole) and cuprous 2-pyridylacetylide (1.66 g, 0.01 mole) in 50 ml of pyridine for 16 hr at 125° yielded *via* procedure B 0.98 g (50%) of benzene–petroleum ether recrystallized acetylene with mp 104–105° (lit.[24] 104–105°); infrared spectrum: C≡C at 2205 and NH_2 at 3470 and 3390 cm^{-1}.

(2-Amino-5-methylphenyl)phenylacetylene.—2-Iodo-4-methylaniline (4.66 g, 0.02 mole) and cuprous phenylacetylide (3.29 g, 0.02 mole) in 100 ml of pyridine at 120° for 6 hr afforded *via* procedure B 3.81 g (0.0184 mole, 92%) of ethanol (Norit) and chloroform–petroleum ether recrystallized acetylene with mp 128.5–129.8°; infrared spectrum: C≡C at 2195 and NH_2 at 3475 and 3380 cm^{-1}.

Anal. Calcd for C, 86.91; H, 6.32. Found: C, 86.57; H, 6.41.

Reducion of Phenacyl Bromide.—Phenacyl bromide (2.73 g, 0.0137 mole) and cuprous phenylacetylide (2.22 g, 0.0137 mole) in 60 ml of ethylene glycol at 140° for 16 hr *via* procedure A yielded 0.75 g (47%) of acetophenone. The infrared spectrum was identical with an authentic sample's. Another liquid product showing no C≡C or C=O absorption in the infrared spectrum was not characterized further. Attempts to condense phenacyl bromide or chloride in a variety of solvents were unsuccessful. The above reduction was also effected with CuBr in DMF–H_2O.

Coupling of Cuprous Phenylacetylide.—4,6-Dibromoresorcinol (4.32 g, 0.015 mole) and cuprous phenylacetylide (4.94 g, 0.03 mole) in 125 ml of pyridine at 125° for 3 hr afforded *via* procedure B 1.72 g (0.0086 mole, 57%) of 1,4-diphenylbutadiyne having an infrared spectrum and mixture melting point identical with those of authentic material.

Similarly 4,6-diiodoresorcinol and cuprous phenylacetylide in glacial acetic acid at 125° for 2 hr yielded 0.82 g (32%) of 1,4-diphenylbuteneyne having mmp 94.5° (lit.[25] 95°) and an infrared spectrum identical with that of authentic material.

Thianthrene.—*o*-Bromothophenol (4.06 g, 0.0215 mole) and cuprous phenylacetylide (3.55 g, 0.217 mole) in 130 ml of pyridine at 125° for 5.5 hr yielded *via* procedure B 0.2 g of sublimed and twice-recrystallized (benzene–petroleum ether) thianthrene having a mmp 158–159 with authentic material; infrared spectrum showed no C≡C or SH.

Anal. Calcd for $C_{12}H_8S_2$: C, 66.62; H, 3.73; S, 29.65. Found: C, 66.97; H, 3.92; S, 29.11.

An unsublimable solid possessing the same analysis after recrystallizing had mp 190–191.5. It was not characterized further.

Starting Materials.—All starting materials and solvents employed in this work had physical properties that checked those of the literature. Impure substances were recrystallized or distilled before use.

2-Ethynylpyridine was obtained from 2-vinylpyridine by the procedure of Leaner.[26] 2-Iodo-4-methylaniline was prepared from *p*-toluidine and iodine according to Wheeler and Liddle.[27] 4-Amino-3-iodophenol was obtained from *m*-iodophenol and diazotized sulfanilic acid followed by reduction with dithionite.[28] O-Iodobenzyl alcohol was obtained from the $LiAlH_4$ reduction of the acid chloride.[29] O-Bromothiophenol was prepared by the method of Saggiomo.[30] O-Iodo-N-ethylaniline was prepared *via* the sodium borohydride reduction of the Schiff base from *o*-iodoaniline and acetaldehyde in ethanol. The crude product was purified by repeated extraction with aqueous $ZnCl_2$ to remove primary amine impurities. The material had bp 81–84° (0.5 mm); infrared spectrum: secondary NH at 3375 cm^{-1}.

Anal. Calcd for $C_8H_{10}IN$: C, 38.85; H, 4.05; I, 51.45. Found: C, 38.98; H, 4.06; I, 51.73.

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