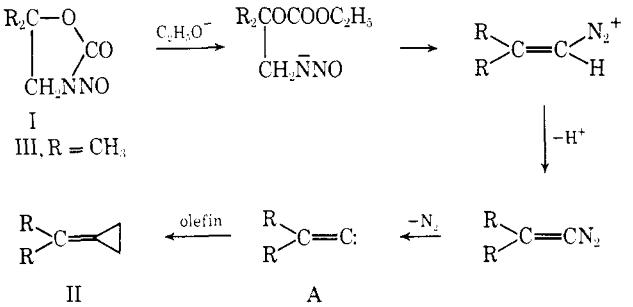
The Reaction of Dimethylethylidenecarbene with Olefins

Melvin S. Newman and Timothy B. Patrick[1]

Contribution from the Evans Chemistry Laboratory of The Ohio State University, Columbus, Ohio 43210. *Received May 24, 1969*

Abstract: Treatment of 5,5-dialkyl-N-nitrosooxazolidones with lithium alkoxides in the presence of olefins affords disubstituted methylenecyclopropanes. The relative rates of reaction of the intermediate, dimethylethylidenecarbene,[2] with styrenes indicate that the olefins act as nucleophiles ($\rho = -3.4$ for p-CH_3, p-H, p-Cl). However, since tetramethylethylene reacts much less rapidly than cyclohexene, a steric effect is operative. A possible steric course for the addition reactions is outlined.

The formation of methylenecyclopropanes (II) on treatment of 5,5-disubstituted N-nitrosooxazolidones (I) with lithium ethoxide in olefins has been used as evidence that unsaturated carbenes (A) are involved.[3,4] In this paper are described the reactions of a number of olefins with dimethylethylidenecarbene[2] prepared by treatment of 5,5-dimethyl-N-nitroso-2-oxazolidone (III) with lithium alkoxides.



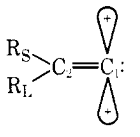
In the best of several experimental procedures lithium ethoxide ethanolate[5] was added to a suspension of III in a large excess of the olefin involved. The reactions were complete after a short time. By conventional procedures the dimethylmethylenecyclopropanes listed in Table I were obtained. In addition to these cyclopropanes, appreciable amounts of oxygenated products were always obtained. After alkaline hydrolysis of these mixtures there were obtained appreciable amounts of 2-methyl-1,2-propanediol. This diol results from courses of reaction which do not involve the base-catalyzed elimination of lithium ethyl carbonate from any intermediate formed in the attack of ethoxide on III. No further discussion of this part of the reaction will be made at this time except to note that the courses of reaction involved are very sensitive to solvent and temperature. In more polar solvents very little unsaturated carbene which can be trapped by an olefin is formed.

Since only *cis*- and *trans*-1-methyl-2-isopropyl(dimethylmethylene)cyclopropane (**12** and **13**, respectively) were obtained from *cis*- and *trans*-4-methyl-2-pentene, respectively, we assume that dimethylethylidenecarbene reacts as a singlet.[6] The assignments of *cis* and *trans* structures to **12** and **13** were based on the von Auwers rule[7] that *cis* products have higher boiling points and indices of refraction than do the *trans* isomers. The nmr spectra were useless for assigning geometry.

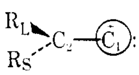
The relative reactivities toward dimethylethylidenecarbene of the olefins listed in Table II were determined by conducting the decomposition of III in large excesses of equimolar solutions of cyclohexene and the olefin at 35–45°. Lithium 2-ethoxyethoxide was used as base as it was soluble in the olefin mixtures used. The yields of cyclopropanes, II, were comparable to those obtained with lithium ethoxide alcoholate.[5] The ratios of the reaction products were determined by vapor phase chromatography.

The results reported in Table II may be explained by assuming that polar and steric properties of the olefins are involved. The ρ value of -3.4 calculated from the results with p-methylstyrene, styrene, and p-chlorostyrene indicates that the olefins are acting as nucleophiles.[8] However, since cyclohexene is more reactive than tetramethylethylene, and cyclopentene is more reactive than 1-methylcyclopentene, some factor other than the nucleophilicity of the olefins is involved. We believe a steric factor is responsible.

In order to explain the steric hindrance to reaction we assume that C_1 of the singlet unsaturated carbene **B** is sp hybridized. Thus, one vacant orbital is in the plane of the paper, as shown in projection B_1, or perpendicular to the plane of the paper, as shown in B_2 (R_S and R_L refer to small and large groups in the general case.)



B_1



B_2

In the addition of an unsaturated carbene to an olefin we assume a two-step mechanism in which the attack is

---

[1] Postdoctoral Research Associate supported by Grant 5552 of the National Science Foundation.

[2] We propose that the nomenclature for the hypothetical unsaturated carbene be based on the structure $>C_2{=}C_1:$, ethylidene carbene. Since substitution can occur only on C_2, numbering of substituents is unnecessary. Thus, $(CH_3)_2C{=}C:$ is called dimethylethylidenecarbene.

[3] M. S. Newman and A. O. M. Okorodudu, *J. Amer. Chem. Soc.*, **90**, 4189 (1968).

[4] M. S. Newman and A. O. M. Okorodudu, *J. Org. Chem.*, **34**, 1220 (1969).

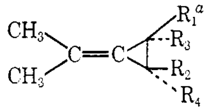
[5] W. M. Jones, M. H. Grasley, and W. S. Brey, Jr., *J. Amer. Chem. Soc.*, **85**, 2754 (1963).

[6] (a) P. S. Skell and A. Y. Garner, *J. Amer. Chem. Soc.*, **78**, 5430 (1956). For reviews see (b) P. P. Gaspar and G. S. Hammond in W. Kirmse, "Carbene Chemistry," Academic Press, New York, N. Y., 1964, pp 235–274; and (c) G. H. Closs, "Topics in Stereochemistry," Vol. III, E. L. Eliel and N. L. Allinger, Ed., Interscience Publishers, New York, N. Y., 1968, pp 193–231.

[7] E. L. Eliel, N. L. Allinger, S. J. Angyal, and G. A. Morrison, "Conformational Analysis," Interscience Publishers, New York, N. Y., 1965, p 172.

[8] The ρ value for the addition of dichlorocarbene (from pyrolysis of $C_6H_5HgCCl_2Br$) to styrenes is -0.6: D. Seyferth, J. Yick-Pui Mui, and R. Damrauer, *J. Amer. Chem. Soc.*, **90**, 6182 (1968).

Table I. Dimethylmethylenecyclopropanes



	R1	R2	R3	R4	Yield,[b] %	Bp (mm),[c] °C	Anal.[d] Calcd, % C	Anal.[d] Calcd, % H	Anal.[d] Found, % C	Anal.[d] Found, % H	Mass spectrum[e] (70 eV)
1	CH_3	CH_3	CH_3	CH_3	21	80–90 (120)	86.9	13.1	86.9	13.1	138 (29), 81
2	$-(CH_2)_6-$		H	H	18	120–125 (30)	87.7	12.3	87.6	12.3	160 (4), 67
3	$-(CH_2)_5-$		H	H	43	100–110 (15)	87.9	12.1	87.9	12.1	150 (29), 41
4	$-(CH_2)_4-$		H	H	56	100–108 (110)	88.2	11.8	88.0	11.8	136 (24), 93
5	$-(CH_2)_3-$		H	H	30	132–134 (760)	88.4	11.6	88.3	11.7	122 (40), 79
6	$-(CH_2)_3-$		CH_3	H	27	105–110 (135)	88.2	11.8	88.0	11.9	136 (83), 121
7	$(CH_3)_3CO$	H	H	H	31	*g*	77.9	11.8	78.1	11.9	150 (29), 41
8	*p*-$CH_3C_6H_5$	H	H	H	37	49–49.5 (0.1)	90.6	9.4	90.4	9.4	172 (15), 157
9	C_6H_5	H	H	H	32	52–54 (0.4)	91.1	8.9	90.8	9.1	158 (15), 144
10	*p*-ClC_6H_5	H	H	H	19	75–85 (1)	74.8	6.8	74.8	7.0	192 (3), 157
11	$CH_3(CH_2)_5-$	H	H	H	31	*g*	86.7	13.3	86.4	13.3	166 (5), 67
12	CH_3	$(CH_3)_2CH$	H	H	30	124–126 (750)[h]	86.9	13.1	86.7	13.2	138 (10), 67
13	CH_3	H	H	$(CH_3)_2CH$	34	108–110 (750)[i]	86.9	13.1	86.7	13.2	138 (8), 67

[a] The infrared spectrum of each compound contained a weak C=C absorption at 5.50–5.60 μ. The nmr spectra of compounds **8**, **9**, and **10** contained signals with slight coupling at approximately τ 8.1 and 8.2 due to the nonequivalent isopropylidene methyls. All other compounds showed this methyl absorption as a singlet (sometimes broad) at τ 8.20–8.29. [b] Yields of pure products isolated by distillation are reported on the best of two runs except for compound **4** which is the best of five runs. Yields determined by vpc were 10–30% higher than the isolated yields. [c] Boiling ranges were determined on a semimicrodistillation apparatus. Vpc showed one peak in each case. [d] Analytical samples were obtained by preparative vpc. [e] The first value is the molecular ion. The value in parentheses is the intensity of the molecular ion. The last value is the ion of greatest intensity. Recorded on an AEI-MS-9 mass spectrometer at 70 eV. [f] M. Tanabe and R. A. Walsh, *J. Amer. Chem. Soc.*, **85**, 3522 (1965). [g] Isolated by preparative vpc on a 10 ft × 3/8 in. 20% Carbowax 20M at 80°, flow 90 ml/min, retention time 10 min (compound **11**, 95°, 85 ml/min, 13 min). [h] *cis* n^{26}D 1.4419, determined on a vpc homogeneous sample. [i] *trans* n^{26}D 1.4319, determined on a vpc homogeneous sample.

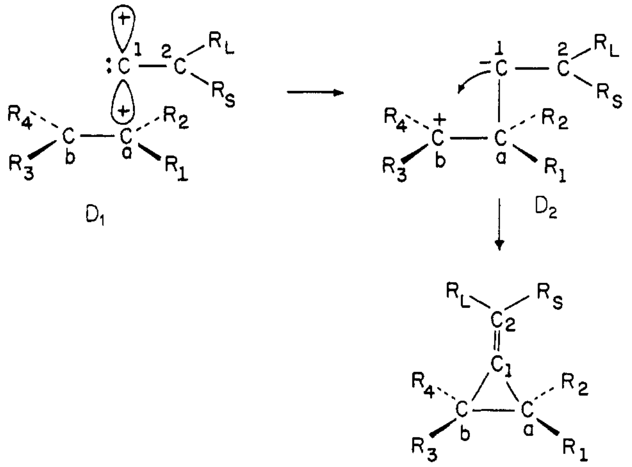
Table II. Relative Rates of Addition of Dimethylethylidenecarbene to Olefins[a]

Olefin	Relative rate[b]
p-Methylstyrene	71[c]
Styrene	6.2
p-Chlorostyrene	2.6[c]
Cyclopentene	1.1 (1.2)[d]
Cyclohexene	1.0
Tetramethylallene	0.9
Cyclooctene	0.7
Cycloheptene	0.6
cis-4-Methyl-2-pentene	0.5 (0.6)[e]
t-Butoxyethylene	0.4 (0.4)[f]
1-Methylcyclopentene	0.3
1-Octene	0.2
trans-4-Methyl-2-pentene	0.07
Tetramethylethylene	0.02 (0.03)[d]
Tetrachloroethylene	0.0

[a] The approximate error is $\pm 5\%$. [b] Measured in competition with cyclohexene. Reported values are averaged from two to five runs. [c] Measured in competition with styrene and corrected to cyclohexene. [d] Measured in competition with 1-methylcyclopentene and corrected to cyclohexene. [e] Measured in competition with *trans*-4-methyl-2-pentene and corrected to cyclohexene. [f] Measured in competition with cyclooctene and corrected to cyclohexene.

at the carbon a bearing R_1 and R_2 and from a direction perpendicular to the plane of the olefin which is in the plane of the paper. The carbene, B_2, is oriented so that R_S and R_L are in the plane of the paper and R_S is nearer R_1 and R_2 and between R_1 and R_2, as shown in the projection D_1. In step 1 a bond is formed between C_1 and C_a to yield the dipolar ion D_2 which cyclizes in the second step to form the methylenecyclopropane II in which R_S is nearer R_1 and R_2. If the time from step 1 to step 2 is very short, essentially a one-step mechanism would be involved.

Different orientations of B_2 as it reacts with the olefin may be represented (*e.g.*, at angles up to 90° to the double bond of the olefin) but various degrees of twisting would then be required to end up with the structure II. In any case predictions as to the geometry of the products expected can be made. We hope to be able to test the suggested mechanism.

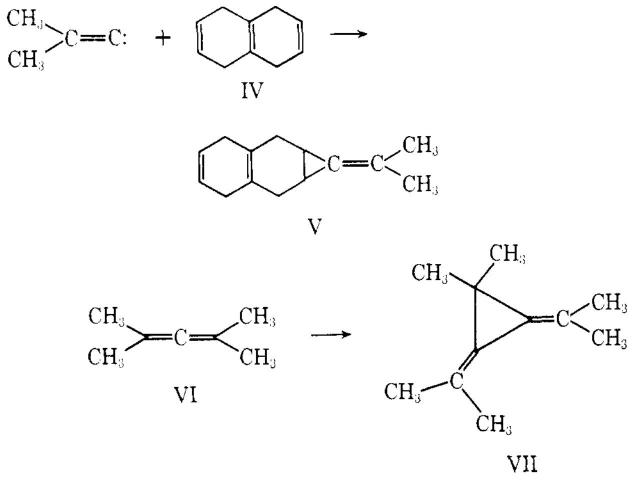


If one accepts this picture of the mechanism, the steric effect which slows down the rate of addition to methylcyclopentene (0.3) as compared to cyclopentene (1.1) may function in two ways: one, a statistical argument that in methylcyclopentene D_1 (assuming that R_1 and R_3 form the ring, R_2 is H and R_4, CH_3) is more easily formed than D_1 (in which R_2 is CH_3 and R_4, H), whereas in cyclopentene both orientations in D_1 are comparable to the favored D_1 in methylcyclopentene; the second, that even when the carbene adds to give D_1 in which R_2 is H, the closure to III is slowed because of greater strain between R_L with R_3 and R_4 when R_4 is CH_3 than H. Similarly the slower rate of tetramethylethylene (0.02) as compared to cyclohexene (1.0) is explained on steric grounds.

The addition of dimethylallenidenecarbene[9] to tetramethylethylene is about 20-fold more rapid than to cyclohexene. Hence, the steric effect mentioned above is not operative. In allenidene carbenes, assuming a singlet state is involved,[9] the vacant electrophilic orbital lies in a plane perpendicular to the plane which contains the methyl groups. Thus the steric repulsion described above for ethylidene carbenes is not operative.

Interestingly, when 1,4,5,8-tetrahydronaphthalene[10] (IV) was used to trap dimethylethylidenecarbene, the product was entirely *cis*-1a,2,3,6,7,7a-hexahydro-1-isopropylidene-1H-cyclopropa[*b*]naphthalene (V). This result stands in contrast to those obtained by addition of other carbenes to IV.[11] The steric effect above described can account for this result.

When tetramethylallene (VI) was used in the reaction medium a 14% yield of 2,3-bis(isopropylidene)-1,1-dimethylcyclopropane[12] VII was obtained. The identity of VII was established by infrared and nmr analysis.


IV

V

VI

VII

Experimental Section

Temperature readings are uncorrected. Elemental analyses were performed by Galbraith Laboratories, Inc., Knoxville, Tenn. Preparative vpc was done on an Aerograph Autoprep Model A-700. The term "worked up as usual" means that an ether–benzene solution of the products was washed with acid and/or alkali with saturated salt solution and was then dried by filtration through anhydrous magnesium sulfate. The solvents were removed and the products purified by conventional methods.

5,5-Dimethyl-2-oxazolidone. To 196.0 g (1.3 mol) of ethyl 3-hydroxy-3-methylbutyrate[13] was added 54.0 g (1.9 mol) of anhydrous hydrazine. The exothermic reaction was held at 35–40° by cooling. The hydrazide solidified on standing overnight. Recrystallization from 500 ml of chloroform gave colorless plates of the hydrazide, mp 99.5–100°, in almost quantitative yield.

A solution of 50.0 g (0.38 mol) of the above hydrazide in 300 ml of 6 *N* hydrochloric acid was treated at −5° with a solution of 30.0 g (0.43 mol) of sodium nitrite in 100 ml of water during 30 min. Following the addition, a positive nitrous acid test was obtained. The cold solution was extracted with 1.5 l. of 3:1 benzene–chloroform which was then washed with saturated sodium chloride solution. The cold azide solution was added dropwise to 100 ml of stirred benzene at reflux during 1.5 hr. Removal of the solvents gave 33.5 g (77%) of 5,5-dimethyloxazolidone, mp 76–78°. Vaporization at 80° (0.05 mm) occurred with little loss to give white crystals, mp 77–79°.[14]

5,5-Dimethyl-N-nitrosoxazolidone (III) was prepared by method A as described.[15] By crystallization from ether there was obtained a 94% yield of III, mp 88.5–89.5.°[15]

Lithium 2-Ethoxyethoxide. To a stirred mixture held at 0° of 4.0 g of pure lithium[16] wire cut in $^1/_8$-in. lengths in 75 ml of dry hexane was added dropwise 40 g of 2-ethoxyethanol (ethyl Cellosolve) during 1 hr. The hexane solution was flushed under nitrogen into a polyethylene container and placed in the freezing box of a refrigerator overnight. The alkoxide crystallized to give 15.0 g (37%) of white crystals which were filtered quickly and stored in the freezer. A hexane solution of the alkoxide did not evolve hydrogen on treatment with sodium hydride. Titration with 0.100 *N* hydrochloric acid indicated a purity of 99.8%.

Preparation of Dimethylmethylenecyclopropanes (1–13) and 2,3-Bis(isopropylidine-1,1-dimethylcyclopropane (VII). The preparation of 1-isopropylidenebicyclo[4.1.0]heptane (**4**) will be described as a model by which compounds **1–13** and VII were prepared.

A stirred mixture of 5.0 g (0.035 mol) of III in 30 ml of dry cyclohexene at 45–55° was treated in three equal portions with 5.0 g (0.051 mol) of lithium ethoxide monoethanolate.[5] Each addition caused vigorous nitrogen evolution which was usually complete and quantitative within 5–10 min. The reaction mixture was poured into ice–water. Following the usual work-up, the residue was distilled at 100–108° (110 mm) to give 2.1 g (56%) of **4**, *ca.* 95% by vpc. Analytically pure material was obtained by preparative vpc on 20 ft × 0.5 in., 30% SE-30 at 70°, helium flow 100 ml/min, retention time 15 min.

The oil remaining after distillation of compounds **1–13** yielded 0.5–1.5 g of a mixture of products, bp 80–120° (0.1 mm). Hydrolysis of 0.3 g of this mixture with alcoholic potassium hydroxide gave 0.1 g of 2-methyl-1,2-propanediol, identical with an authentic sample.

Competitive Reactions with Olefins. A solution of 0.5 g (0.0051 mol) of lithium 2-ethoxyethoxide in 5 g (0.06 mol) of cyclohexene and an equivalent amount of competing olefin was treated at 40° with 0.5 g (0.0035 mol) of III all at once. Nitrogen evolution occurred immediately and was complete and quantitative within 5 min. The mixture was poured into water and the organic solution was separated, dried, and analyzed by vpc. A 5 ft × $^1/_8$ in. column of 10% XE-60 on Chromosorb W, 60–80 mesh at 45–55° and nitrogen flow of 30–50 ml/min, was used for separation in an F & M Model 609 flame ionization gas chromatograph. A 5 ft × $^1/_8$ in. column of 5% diethylene glycol succinate was used when styrene was the competing olefin. The yields of dimethylmethylenecyclopropanes (estimated by vpc) were 50–65%. The products were stable to the reaction and vpc conditions. Relative reactivities reported in Table II were calculated from the expression $k/k_0 = P/P_0$, where P = moles of product formed from competing olefin and P_0 = moles of **4** formed.

***cis*-1a,2,3,6,7,7a-Hexahydro-1-isopropylidene-1H-cyclopropa[*b*]naphthalene (V).** To a stirred mixture of 6.0 g of lithium ethoxide monoethanolate, 9.0 g of 1,4,5,8-tetrahydronaphthalene (IV)[10] and 40 ml of dry hexane was added 5.5 g of III in one portion. After 30 min at room temperature, the mixture was poured into water and worked up as usual. Removal of the hexane gave 11.0 g of yellow oil which crystallized on standing. Vpc analysis on 5 ft × $^1/_8$ in. column of 10% XE-60 on Chromosorb W at 75° showed that the oil consisted of 2.9 g (40%) of V in addition to unreacted starting material. No other products were detected. Preparative vpc (10 ft × $^3/_8$ in. column of 20% Carbowax 20M at 140°, 150 ml helium/min, retention time, 7 min) gave a colorless liquid which

---

[9] H. D. Hartzler [*J. Amer. Chem. Soc.*, **83**, 4990, 4997 (1961)] uses different nomenclature for the carbene involved. We propose that allenic carbenes be named allenidenecarbene as follows: $R_2C_3{=}C_2{=}C_1$:. Since substitution can occur only on C_3, no numbers are needed to denote substitution.

[10] We thank Drs. L. Paquette and C. Phillips for a sample of IV.

[11] J. J. Sims and V. K. Honwad [*J. Org. Chem.*, **34**, 496 (1969)] show that monochlorocarbene is less selective than dichlorocarbene.

[12] R. F. Bleiholder and H. Shechter, *J. Amer. Chem. Soc.*, **86**, 5032 (1964).

[13] H. Machleidt, V. Hartmann, and H. Bunger, *Ann.*, **667**, 35 (1963).

[14] W. J. Close, *J. Amer. Chem. Soc.*, 73, 95 (1951), mp 79–82°.

[15] M. S. Newman and A. Kutner, *ibid.*, 73, 4199 (1951), mp 87.7–89.8°.

[16] Pure lithium (sodium free) was obtained from Foote Mineral Co.

crystallized to a white solid: mp 30.8–31.2°; ir (neat) 5.50 (methylenecyclopropyl) and 6.05μ (C=C); nmr (CCl_4 with TMS standard on Varian A-60) τ 8.68 (rounded, 2 H, cyclopropyl), 8.52 (singlet with slight coupling, 6 H, CH_3), 8.13 (rounded singlet, 4 H, CH_2 adjacent to cyclopropane ring), 7.85 (sharp singlet, 4 H, CH_2 between ethylenes), and 4.16 (singlet, 2 H, vinyl protons).

Anal. Calcd for $C_{14}H_{18}$: C, 90.3; H, 9.7. Found: C, 90.3; H, 9.8.

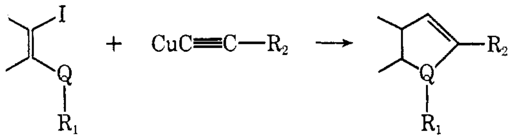
Copper(I) Substitutions. Scope and Mechanism of Cuprous Acetylide Substitutions

C. E. Castro, R. Havlin, V. K. Honwad, A. Malte, and Steve Moje

Contribution from the Department of Nematology, University of California, Riverside, California 92502. *Received June 23, 1969*

Abstract: Substitutions with cuprous acetylides provide a most convenient route to a wide variety of acetylenes and heterocyclic arrays. This summarizing work casts these reactions into a general pattern for copper(I) substitution. The reactivity of acetylides toward bond type, the kinetics of aromatic substitution, the geometry of allylic substitution, the nature and path of the heterocyclic synthesis, and some mechanistically instructive ring size experiments are presented. Additional heterocyclic syntheses are described. The mechanisms for reaction range from a four center process (aryl halide substitution) to homolytic scission (oxidation with N-bromosuccinimide). The stereochemistry of the cuprous chloride-catalyzed hydrolysis of allylic halides is portrayed and the reaction of these salts with halohydrins is described.

The reaction of cuprous acetylides with aryl halides has proven to be a most effective route to a wide variety of aromatic acetylenes.[1] Moreover, the substitution and cyclization of halides bearing a neighboring nucleophilic substituent is now the basis of a versatile heterocyclic synthesis (eq 1). Thus, indoles,



(1)

benzofurans, phthalides,[1a] thianaphthenes,[2] furans,[3] and a range of polynuclear multiheterocyclic arrays[4] are easily obtained in high yield. Indeed, the results at hand suggest an extremely broad scope for the reaction in this domain and some additional ring systems are reported herein.

The present summarizing work is intended to cast these reactions into a general pattern for Cu(I) substitutions. A general reactivity of the acetylides toward bond type, the kinetics of aromatic substitution, the stereochemistry of allylic substitution, and some mechanistically instructive ring-size experiments are presented. The characteristics of several compounds we have not previously reported are given in the experimental section.

Results

Reactivity. A broad range of studies indicates the following pattern of reactivity of halogen (x) bond types toward substitution with cuprous acetylides in dimethyl formamide (DMF): ArSX, ArX > RCOX >> benzyl-X, allyl-X, phenacyl-X > alkyl-X, vinyl-X. The order of reactivity for halogen in all families of compounds is I > Br > Cl. Thus, aryl halides and sulfenyl halides are easily substituted in many solvents at 110° or less. The media of choice for these halides are pyridine and acetonitrile, respectively. An amplification of the influence of substituents upon the rates of substitution of aryl halides is given in the kinetic section. The insensitivity of the aryl halide substitution to solvent is illustrated in the conversion of *o*-iodophenol to 2-phenylbenzofuran. The reaction takes place in high yield in pyridine, dimethylformamide, dimethyl sulfoxide, ethylene glycol, and acetic acid.[5] Although acyl halides react in dimethylformamide slowly, best conversion conditions are mixing neat at room temperature. The benzylic, allylic, and phenacyl systems are loathe to react in DMF at 120°, but they may be substituted at higher temperatures.[3] In contrast, vinyl and saturated aliphatic halides are inert toward substitution at 220° neat or in N-methylpyrrolidone.

We have not previously described the relatively mild substitutions of sulfenyl or acyl halides. Best yield conditions are typified by eq 2 and 3. Moreover, halide substrates that are prone to homolytic scission do not

(2)

R = phenyl, 80%;
n-propyl, 70%

---

(1) (a) C. E. Castro, E. J. Gaughn, and D. C. Owsley, *J. Org. Chem.*, **31**, 471 (1966), and references therein; (b) M. D. Rausch, H. Siegel, and L. P. Kleman, *ibid.*, **31**, 2703 (1966); (c) S. A. Kandil and R. E. Ressey, *J. Amer. Chem. Soc.*, **88**, 3027 (1966); (d) R. E. Atkinson, R. F. Curtis, and J. A. Taylor, *J. Chem. Soc.*, 578 (1967); (e) R. E. Atkinson, R. F. Curtis, D. M. Jones, and J. A. Taylor, *Chem. Commun.*, **14**, 718 (1967); (f) A. M. Sladkov and L. Yu. Ukhin, *Russ. Chem. Rev.*, **37**, 1750 (1968), and references therein.

(2) A. M. Malte and C. E. Castro, *J. Amer. Chem. Soc.*, **89**, 6770 (1967).

(3) K. Gump, S. W. Mojé, and C. E. Castro, *ibid.*, **89**, 6770 (1967).

(4) S. A. Mladenovic and C. E. Castro, *J. Heterocycl. Chem.*, **5**, 227 (1968).

(5) R. D. Stephens and C. E. Castro, *J. Org. Chem.*, **28**, 3313 (1963).