Preparation of Fluorine-Containing Phenylacetylenes by the Method of Introduction of the Ethynyl Group Using 1,1-Dichloro-2,2-difluoroethene

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Phenylacetylenes (ArC≡CH) having fluoro- or trifluoromethyl substituents (o-, m-, p-F; o-, m-, p-CF$_3$; 2,4-, 2,5-, 2,6-, 3,5-(CF$_3$)$_2$) have been prepared from bromobenzenes (ArBr) and benzenes (ArH) using 1,1-dichloro-2,2-difluoroethene (1) by a two-step route: ArLi or ArMgBr→ArCF=CCl$_2$→ArC≡CLi. Upon careful treatment at −70 °C with 1, o-fluorophenyllithium gave o-FC$_6$H$_4$CF=CCl$_2$ in good yield, together with benzyne-derived products, such as o-(o-FC$_6$H$_4$)C$_6$H$_4$CF=CCl$_2$. Lithiation of m-bis(trifluoromethyl)benzene at 0 °C for 9 h (24 h) followed by treatment with bromine gave 1-bromo-2,4-, 2,6-, and 3,5-bis(trifluoromethyl)benzene in 35 (38), 31 (36), and 8% (6%) yield, respectively.

In connection with projects to prepare polymers of fluorine-containing acetylenes and diacetylenes and to examine their applications, it became neccessary to prepare phenylacetylenes having fluoro or trifluoromethyl substituents. Previously, such phenylacetylenes were prepared mostly[1] from the corresponding acetophenones[2-4] and styrenes.[5,6] When relatively inexpensive bromofluorobenzenes and bromo(trifluoromethyl)benzenes are used as the starting material,[7] these routes require at least four steps,[5,6,8] and the overall yields of these multistep preparations are often low. Palladium-catalyzed coupling with ethynyltrimethylsilane followed by a hydrolytic removal of the trimethylsilyl group is a recently developed method for the conversion of aryl bromides (or iodide) into the corresponding arylacetylenes.[9,10] m-(Trifluoromethyl)-phenylacetylene was prepared by this method with an overall yield of 40%.[10]

The method of introduction of the ethynyl group using 1,1-dichloro-2,2-difluoroethene (CF$_2$=CCl$_2$, 1), presented previously by one of us,[11,12] seemed to be easily applicable for the preparation of phenylacetylenes having fluoro or trifluoromethyl subsituents. A subsequent study has shown that not only the phenylacetylenes having m-F, p-F, o-CF$_3$, m-CF$_3$, and p-CF$_3$

as substituents are prepared in overall yields ranging from 48 to 69%, starting with the corresponding bromobenzenes, but also this method is applicable for the preparation of o-fluorophenylacetylene, for which the reaction of unstable o-fluorophenyllithium with 1 is involved. Furthermore, among the six isomeric bis(trifluoromethyl)phenylacetylenes, on which little information is available, four compounds were obtained. Considerable efforts have also been devoted toward a clarification of complications encountered in the lithiation of m-bis(trifluoromethyl)benzene and in the reaction of the resulting phenyllithiums with 1.

The course of the present synthesis is given in Scheme 1. It consists of the first step: the preparation of the 2,2-dichloro-1-fluoroethenyl intermediates (6) and the second step: the conversion of these intermediates into the corresponding terminal acetylenes 8.[11] The second step was carried out in good yield in every case by using the standard conditions. For the first step, however, the reaction conditions had to be examined in individual cases in order to obtain satisfactory results.

m- and p-FC$_6$H$_4$CF=CCl$_2$ (6b and 6c) were prepared from m- and p-bromofluorobenzene, respectively, both via the Grignard reagents and via the corre-

a	X=o-F	d	X=o-CF$_3$	g	X=2,4-(CF$_3$)$_2$	
b	X=m-F	e	X=m-CF$_3$	h	X=2,5-(CF$_3$)$_2$	
c	X=p-F	f	X=p-CF$_3$	i	X=2,6-(CF$_3$)$_2$	
				j	X=3,5-(CF$_3$)$_2$	k X=o-(o-FC$_6$H$_4$)

Scheme 1. Course of preparation of fluorine-containing phenylacetylenes (8).

sponding organolithium reagents. The yields of **6b** and **6c** obtained via the Grignard reagents **5** were substantially higher than those obtained via the fluorophenyllithiums (**4**). The yields of **6b** and **6c** via the fluorophenyllithiums, when ethereal solutions of the fluorophenyllithiums were not kept cold before and during the addition to solutions of **1**, were even considerably lower than those given in Table 1. It appears that these fluorophenyllithiums[13] have a tendency to form polyphenyls with an elimination of lithium fluoride.

Initially, no attempt was made for the preparation of o-FC$_6$H$_4$CF=CCl$_2$ (**6a**) because of the known tendency of o-fluorophenyllithium (**4a**) to lose lithium fluoride to form benzyne.[14] Later, a careful low-temperature treatment of **4a** with **1** was found to give **6a** in a good yield. The method consists of the preparation of o-fluorophenyllithium (**4a**)[15] at −80 °C, the addition of **1** at lower temperatures, and allowing the

reaction of **4a** with **1** to proceed within a temperature range between −80 and −70 °C until **4a** is mostly consumed. This reaction should be conducted on a small scale with great precaution (see the section of **6a** in Experimental). In this procedure, the formation of products **6k** and **10k** derived from o-(o-fluorophenyl)phenyllithium (**4k**), which results from a decomposition of **4a** into benzyne (**9**) followed by addition of another molecule of **4a**, was more or less unavoidable (Scheme 2). We also obtained a compound to which the structure o-(CF$_2$=CCl)C$_6$H$_4$CF=CCl$_2$ (**12**) was assigned on the basis of spectroscopic data. The formation of **12** could be explained in terms of the addition of CF$_2$=CClLi, which is formed from **1** by a Cl–Li exchange,[11] to **9** followed by a reaction of the resulting lithium compound **11** with **1**.

For the preparation of o-, m-, and p-CF$_3$C$_6$H$_4$CF=CCl$_2$ (**6d**, **6e**, and **6f**) from the respective isomers of bromo-(trifluoromethyl)benzenes, both the route via the

Table 1.   Isolated Yields[a,b] of Dichlorofluoroethenyl
Intermediates (**6**) and Phenylacetylenes (**8**)

Starting compound (**2** or **3**)	Substituent	Yield of **6**/%		Yield of **8**/%
		via **4**	via **5**	
o-Bromofluorobenzene	a	75		87
m-Bromofluorobenzene	b	48	82 (18)	84
p-Bromofluorobenzene	c	62	79 (24*)	82
o-Bromo(trifluoromethyl)benzene	d	77 (1)	0[c] (30)	86
m-Bromo(trifluoromethyl)benzene	e	56	72 (21**)	80
p-Bromo(trifluoromethyl)benzene	f	61 (1)	61 (19**)	78
1-Bromo-2,4-bis(trifluoromethyl)benzene	g	67		78
p-Bis(trifluoromethyl)benzene	h	72		78
1-Bromo-2,6-bis(trifluoromethyl)benzene	i	48[d] (15*)		83
1-Bromo-3,5-bis(trifluoromethyl)benzene	j	80		85
(o-Bromofluorobenzene)	k	9[e]		82

a) Based on charged starting material. b) Total refluxing times (h) with **1** in ether are indicated in parentheses; continuous (unmarked), with one overnight interruption in 2 days (*), with two overnight interruptions in 3 days (**). Where no parenthesized figure is given, the reaction mixture was hydrolyzed without refluxing. c) Determined yield was 0.1%. d) Hexane–ether was used as solvent. Compound **13i** (2,6-(CF$_3$)$_2$C$_6$H$_3$C≡CCl) in 4% yield was also obtained. e) Yield obtained as by-product of the reaction where **6a** was the main product (75%).
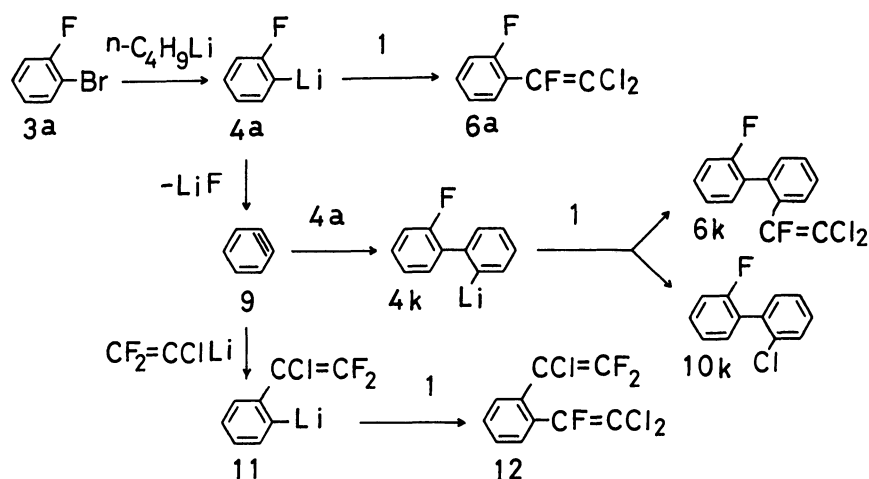
Scheme 2.   Reaction of o-fluorophenyllithium (**4a**) with **1**.

Grignard reagents and the route via the corresponding lithium reagents were examined. In the case of the m-isomer **6e**, the use of the Grignard reagent gave a higher yield, as has been already reported.[11] However, the yield of the p-isomer **6f** obtained from the Grignard reagent was the same as that obtained from the corresponding lithium reagent. Furthermore, o-(trifluoromethyl)phenylmagnesium bromide (**5d**) gave no more than a trace amount of o-$CF_3C_6H_4CF=CCl_2$ (**6d**) upon treatment with **1** under reflux for 30 h, whereas o-(trifluoromethyl)phenyllithium (**4d**) gave **6d** in 77% yield.

The use of (trifluoromethyl)benzene (benzylidyne trifluoride: IUPAC; benzotrifluoride: trivial) as the starting material for the preparation of (trifluoromethyl)phenylacetylenes has two disadvantages: Slow lithiation and the formation of isomers.[16,17] Nevertheless, the low cost and easy availability of (trifluoromethyl)benzene makes this route worth examining. In a typical experiment, 0.9 mol of (trifluoromethyl)benzene was refluxed for 23 h in an ethereal solution of butyllithium prepared from 1 mol of butyl bromide. A subsequent treatment with **1** afforded a mixture of **6d**, **6e**, and **6f**. Since a mutual separation of isomers at this stage was difficult, the mixture was converted into an isomeric mixture of (trifluoromethyl)phenylacetylenes (35% yield of **8d** and 15% yield of **8e+8f** based on unrecovered (trifluoromethyl)benzene) by a treatment with butyllithium. A fractional distillation of this isomeric mixture under reduced pressure gave nearly pure o-(trifluoromethyl)phenylacetylene (**8d**, higher boiling), although the m-isomer **8e** was obtained only as a mixture containing the o-isomer as well as the p-isomer.

The activation of the benzene ring by an additional trifluoromethyl group para to the original trifluoromethyl group makes the lithiation definitely easier. Thus, p-bis(trifluoromethyl)benzene was readily lithiated by a treatment with butyllithium under reflux for 4 h, and subsequent reaction with **1** afforded 2,5-$(CF_3)_2C_6H_3CF=CCl_2$ (**6h**) in 72% yield. The relatively high yield is attributed not only to the formation of a single isomer **4h** from the lithiation of p-bis(trifluoromethyl)benzene but also to the apparent high stability of **4h** in the lithiated mixture. The latter point is in sharp contrast to the instability of **4g** and **4j** in the mixture obtained from m-bis(trifluoromethyl)benzene by lithiation (vide infra).

Lithiation of m-bis(trifluoromethyl)benzene[18,19] gives 2,4- (**4g**), 2,6- (**4i**), and 3,5-bis(trifluoromethyl)phenyllithium (**4j**). Initial attempts to obtain the isomers of $(CF_3)_2C_6H_3CF=CCl_2$ (**6g**, **6i**, and **6j**) by the treatment of such lithiated mixtures with **1** were met with unpredictable and sometimes unreproducible results. After a considerable number of experiments, it was found that 3,5-bis(trifluoromethyl)phenyllithium (**4j**), first, and the 2,4-isomer **4g**, next, tended to

disappear when reaction mixtures obtained by lithiation of m-bis(trifluoromethyl)benzene under refluxing conditions were further refluxed or left standing.[20] The nature of the reaction(s) where **4j** and **4g** are consumed is not clear at present. In addition, a considerable difference in the reactivity with **1** exists between the 2,6-isomer **4i** and the 2,4-isomer **4g** or 3,5-isomer **4j**. These facts, coupled with isomer separation problems, prompted us to examine the preparation of the three isomers **3g**, **3i**, and **3j** of bromobis(trifluoromethyl)benzene, from which individual isomers of bis(trifluoromethyl)phenyllithium are obtained.

The lithiation of m-bis(trifluoromethyl)benzene under ice-cooling for 9 h followed by quenching with bromine and fractional distillation gave 1-bromo-2,4- (**3g**), 2,6- (**3i**), and 3,5-bis(trifluoromethyl)benzene (**3j**) in 35, 31, and 8% yield, respectively. When the time of the lithiation was extended to 24 h under otherwise the same conditions, the yields of **3g**, **3i**, and **3j** were 38, 36, and 6%, respectively. The change in the isomer distribution of the bromobis(trifluoromethyl)benzenes seems to reflect the relative stabilities (durabilities) of the isomeric bis(trifluoromethyl)phenyllithiums in the lithiated mixture stated above. 1-Bromo-3,5-bis-(trifluoromethyl)benzene (**3j**), which was formed only in small yield in the above reactions, was commercially obtained and smoothly converted into 3,5-$(CF_3)_2C_6H_3CF=CCl_2$ (**6j**) in good yield via the corresponding lithium compound **4j**. The yield of the equivalent transformation of 1-bromo-2,4-bis(trifluoromethyl)benzene (**3g**) into 2,4-$(CF_3)_2C_6H_3CF=CCl_2$ (**6g**) was considerably lower.

The reaction of 2,6-bis(trifluoromethyl)phenyllithium (**4i**) with **1** was much slower than those of the other isomers **4g**, **4h**, and **4j** and required hours of refluxing. In initial experiments, 2,6-$(CF_3)_2C_6H_3Cl$ (**10i**) was the predominant product accompanied by a smaller proportion of 2,6-$(CF_3)_2C_6H_3CF=CCl_2$ (**6i**). The Cl–Li exchange represented by Eq. 2 was initially regarded as the main route of **10i** since reaction (2) is suggested to be relatively favored when the substitution reaction (1) is sterically retarded.[11] In this particular case, course (3) is also considered important in view of the formation of 2,6-$(CF_3)_2C_6H_3$-$C\equiv CCl$ (**13i**) and 2,6-$(CF_3)_2C_6H_3C\equiv CC_6H_3(CF_3)_2$-6,2. However, in some of the initial experiments **6i** was obtained in relatively good yield. In order to elucidate the factors responsible for such a variation in the yield of **6i**, we carried out a number of experiments and finally found experimental conditions under which 2,6-$(CF_3)_2C_6H_3CF=CCl_2$ (**6i**) was obtained consistently in about 50% yield based on **3i** (see Experimental).
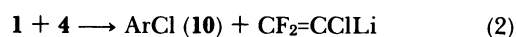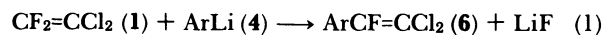
$$CF_2=CCl_2 \ (1) + ArLi \ (4) \longrightarrow ArCF=CCl_2 \ (6) + LiF \quad (1)$$

$$1 + 4 \longrightarrow ArCl \ (10) + CF_2=CClLi \quad (2)$$

$$6 + 4 \longrightarrow ArCF=CClLi + 10 \quad (3)$$

Table 2. Physical Properties[a] and Elemental Analysis Data of Dichloro-
fluoroethenyl Intermediates (6) and Phenylacetylenes (8)

Compd	Bp/ °C(mm Hg)[b]	n_D^{20} or [Mp/°C][c]	19F NMR δ[d] I[e]	19F NMR δ[d] II[f]	1H NMR δ[d] I[g]	1H NMR δ[d] II[h]	IR[i]/cm⁻¹	C(%) (Calcd) Found	H(%) (Calcd) Found
6a	107(33)	1.5285	−31.0[j]	−13.2 (d9.0)		6.94—7.54	1660	(45.97) 45.96	(1.93) 1.86
6b	111(30)	1.5438	−33.0[j]	−18.6 (d2.4)		6.93—7.53	1645	(45.97) 46.05	(1.93) 1.85
6c	110—111(30)	1.5411	−30.1[j]	−17.5		7.04(t 8.7) 7.62(d8.5) (d5.0)	1645	(45.97) 46.14	(1.93) 2.14
6d	110(30)	1.4815	17.3 (d8.8)	−6.4 (q8.9)		7.45—7.86	1664	(41.73) 41.74	(1.56) 1.62
6e	110(30)	1.4974 (1.4970)[k]	15.6	−19.2		7.38—7.97	1645sh		
6f	115(30)	1.5004	15.3	−19.4		7.59(8.7)[l] 7.72(8.7)[l]	1645sh	(41.73) 41.97	(1.56) 1.74
6g	101(30)	1.4452	16.8 (d9.9) 14.9	−8.4 (q9.6)		7.70(8.5)[l] 7.87(8.5)[l] 7.98	1667	(36.72) 36.51	(0.92) 0.86
6h	96(30)	1.4422	16.5 (d9.9) 14.7	−8.1 (q9.6)		7.85[m]	1668	(36.72) 37.00	(0.92) 0.99
6i	108—111(30)	[26.5—28]	17.7 (d6.8)	−5.5 (sep6.8)		7.72(ca.8)[n] 7.96(ca.8)[n]	1667	(36.72) 36.47	(0.92) 0.83
6j	109(30)	1.4457	15.0	−20.9		7.91(1H) 8.14(2H)	1645sh	(36.72) 35.63	(0.92) 0.86
6k	ca.110(1)	1.5771	−37.9[j]	−8.4		6.98—7.60	1657	(58.97) 58.30	(2.83) 2.96
8a	59(30)	1.5252 (1.524)[o]	−31.5[j]		3.27	6.88—7.53	**2114** 3300		
8b	61(50)	1.5151 (1.514)[o]	−34.2[j]		3.06	6.78—7.27	**2107** 3300		
8c	52(30)	[ca.25] ([25—27])[p]	−31.7[j]		3.00	6.93(t 8.2) 7.39(d5.3) (d8.7)	**2110** 3295 3305sh		
8d	ca.70(40)	1.4756 (1.4775)[q]	16.2		3.31	7.20—7.66	**2118** 3303		
8e	69(53)	1.4634 (1.4672)[q]	15.3		3.09	7.27—7.77	**2112**w 3300sh 3312		
8f	56(31)	1.4652 (1.4642)[q]	15.4		3.14	7.49	**2112**w 3300 3315sh		
8g	66(30)	1.4307	15.5 15.0		3.47	7.68[r] 7.69[r] 7.84	**2116** 3314 3330sh	(50.43) 50.48	(1.69) 1.65
8h	67(30)	1.4290	15.5 14.7		3.43	7.63(8.5)[l] 7.73(8.5)[l] 7.83	**2122** 3307	(50.43) 50.43	(1.69) 1.82
8i	70(30)	[56—57]	16.2		3.67	7.48(ca.8)[n] 7.78(ca.8)[n]	**2122** 3320	(50.43) 50.62	(1.69) 1.59
8j	74(60)	1.4221	14.9		3.20	7.77(1H) 7.82(2H)	**2125** 3312	(50.43) 50.40	(1.69) 1.60
8k	ca.80(1)	1.6006	−36.3[j]		2.92	7.00—7.69	**2108** 3293 3290sh	(85.69) 85.37	(4.62) 4.63

a) All the compounds listed in the table showed the molecular peaks in mass spectroscopy. b) Not neccessarily accurate enough to give a correct boiling point order for isomers due to the uncertainty in pressure measurement in mutually independent experiments. c) Literature values given in parentheses. d) 20% solution in CDCl₃. ¹H and ¹⁹F chemical shifts measured downfield relative to internal tetramethylsilane and relative to external CF₃CO₂H, respectively. Splitting pattern and (apparent) coupling constant (Hz) indicated in parentheses. e) ¹⁹F chemical shift for the trifluoromethyl group and the fluorine atom on the benzene ring. f) ¹⁹F chemical shift for -CF=CCl₂. g) ¹H chemical shift for -C≡CH. h) ¹H chemical shif for ring protons. i) ν(C=C) of -CF=CCl₂ and ν(C≡C) (in bold face) and ν(C-H) of -C≡CH are given. Neat for liquid and in KBr pellet for crystals. w, weak; sh, shoulder. j) Center of complex signals spreading over 25—31 Hz (0.45—0.55 ppm). k) Ref. 11. l) AB pattern. m) A sharp signal with a broad base (δ=7.66—7.94). n) AB₂ pattern. The upper value represents A. o) Ref. 5 (n_D^{25}). p) Ref. 2. q) Ref. 6. r) Probably the center signals of an AB pattern though the outer signals are not clear.

$$ArCF=CClLi \longrightarrow ArC{\equiv}CCl \text{ (13)} + LiF \qquad (4)$$

Unexpectedly, the use of a freshly prepared sample of 1[21] was found to be the most important requirement for the formation of 6i with a reasonable yield. It appears that partially deteriolated samples of 1 contain a compound or compounds (possibly, the epoxide of 1 and/or its secondary products) which gives ArCl upon reaction with ArLi, probably by a Cl–Li exchange.   Generally, the reaction of an aryllithium with such a compound is not considered important since the reaction of the aryllithium with 1 proceeds rapidly.   In the case of 2,6-bis(trifluoromethyl)phenyllithium, however, the reaction with 1 giving 6i is slow and, thus, the suspected reaction will become important. If this is the case, the use of a large excess of a (deteriolated) sample of 1 is particularly undesirable for the preparation of 6i.

The dichlorofluoroethenyl intermediates 6 prepared as mentioned above were converted into the corresponding phenylacetylenes (8) in good yield in all cases by treatment with 2 equivalents of butyllithium[11] in ether at about −50 °C. Pure products 8 were isolated by vaccum distillation. For an easy isolation of pure 8 by distillation, it is essential to use a sample of ArCF=CCl₂ (6) free from ArCl(10), which is a by-product of the reaction of ArLi (4) with 1 and has a boiling point close to that of ArC≡CH (8).

The present study has proved that the method of introducing the ethynyl group using 1[11] is suitable for the laboratory preparation of fluorine-containing phenylacetylenes 8a through 8j.   Preparations on up to a 0.5—1 mol scale were relatively easily performed with no apparent danger, except for the reaction of o-fluorophenyllithium (4a) with 1.   The inverse addition method, which is relatively safe and generally used for the preparation of the dichlorofluoroethenyl intermediates 6 as well as for their conversion into acetylenes 8 involving 8a, is difficult to apply for the preparation of 6a from unstable 4a. The reaction procedure described in the experimental section of 6a, if the temperature control fails, can be hazardous and, thus , has to be carried out with great precaution on a small scale.

The ¹H chemical shift of the acetylenic protons (Table 2) seems to be closely related to the acidity of the prepared phenylacetylenes (8).   The trifluoromethyl group, when it is in the o-position, has a marked effect on the ¹⁹F chemical shift of the –CF =CCl₂ group. The trifluoromethyl group present ortho to the dichlorofluoroethenyl group is also clearly indicated by a relatively large constant of coupling with the fluorine atom of the dichlorofluoroethenyl group. A clear difference was also found in the mass spectroscopy between the dichlorofluoroethenyl compounds with and without the o-trifluoromethyl group. For each of 6a, 6b, 6c, 6e, 6f, and 6j, which has

no o-CF₃ group, the molecular peak is the strongest (100%), and the intensity of the M−Cl peak is in the range 23—45%. In contrast, for each of 6d, 6g, 6h, and 6i, which has at least one o-CF₃ group, the M−Cl peak is the strongest (100%), and the intensity of the molecular peak is in the range 59—85%.

Experimental

Temperature readings are uncorrected. Pressure readings are given in terms of mmHg (1 mmHg=133.322 Pa). ¹⁹F NMR[22] and ¹H NMR spectra were recorded on a Hitachi R-20BK operated at 56.451 MHz and on a Hitachi R-22 operated at 90 MHz, respectively. IR spectra were recorded on a Hitachi EPI-G3 or 285H, and mass spectra on a Shimadzu GCMS-7000. For an integration of the GC peak area, a Shimadzu C-R2AX was used.   Compound 1 was prepared as described previously.[11] Other fluoro chemicals were obtained from PCR Inc., Lancaster Synthesis Ltd., Fluorochem Ltd., Yarsley Research Laboratories, and Central Glass Co. Ltd. (Tokyo). All reactions of organolithium and Grignard reagents were conducted under an atmosphere of nitrogen using sodium-dried ether. Ethereal butyllitium was generally prepared from butyl bromide with cut pieces of lithium in ether under nitrogen. However, an argon atmosphere was neccessary for a smooth preparation of butyllithium from more recently obtained samples of lithium.   The amount of butyllithium is calculated from the nominal concentration.   In the case where a portion of the worked-up mixture was reserved, the fraction (e.g., 0.90) actually subjected to vaccum distillation is necessary for a yield calculation and is indicated as "÷0.90".

o-(2,2-Dichloro-1-fluoroethenyl)fluorobenzene (6a). To a solution of o-bromofluorobenzene (40.0 g, 0.229 mol) in ether (300 ml) mechanically stirred and cooled between −90 °C and −100 °C in a liquid-nitrogen bath (a stainless steel Dewar), ethereal butyllithium (160 ml, 0.267 mol) was added.   The temperature was then maintained at about −80 °C for 1 h, lowered to about −90 °C, and 1 (59 g, 0.44 mol) was added.   The temperature of the resulting mixture was carefully watched and maintained at −70 °C (±3 °C) for 1 h by an occassional adjustment of the bath height with a lab jack. The mixture was then allowed to warm to −60 °C over 30 min and to −50 °C over another 30 min.   (Caution: The temperature should not be allowed to approach −60 °C before the reaction for at least 1 h at −70 °C (or at least 2 h at −80 °C).   Otherwise, uncontrollably rapid temperature rise may be started resulting in dangerous sudden vaporization of the flask content.)   When the temperature reached −27 °C after an additional 30 min, the mixture was hydrolyzed by pouring it onto a mixture of concd hydrochloric acid (27 ml) and crushed ice. Workup and fractional distillation afforded 6a (35.0 g, ÷0.98, 75%), bp 107 °C(30 mmHg). Also obtained were 1-(1-chloro-2,2-difluoroethenyl)-2-(2,2-dichloro-1-fluoroethenyl)benzene (12, 1.2 g, 2%), bp 60 °C(1 mmHg), 2-chloro-2'-fluorobiphenyl (10k, 0.3 g, 1%), bp ca 90 °C(1 mmHg), and 1-(2,2-dichloro-1-fluoroethenyl)-2-(o-fluorophenyl)benzene (6k, 2.9 g, 9%), bp ca. 109 °C(1 mmHg).

10k: Mp 76—77 °C. ¹H NMR δ=6.92—7.47. ¹⁹F NMR δ=−34.58 (m). Found: C, 69.96; H, 3.76; M⁺, 206. Calcd for

$C_{12}H_8ClF$: C, 69.74; H, 3.90; M, 206.

12: n_D^{20} 1.5289. IR (neat) 1738 (CF_2=CCl-) and 1658 cm^{-1} (CCl$_2$=CF-). ^{1}H NMR δ=7.41 (a sharp signal with a broad base: δ=7.24—7.52). ^{19}F NMR δ=−6.1 (1F, d, J=31 Hz), −9.5 (1F, dd, J=31 and 2 Hz), and −11.0 (1F). Found: C, 41.61; H, 1.31; M$^+$, 286. Calcd for $C_{10}H_4Cl_3F_3$: C, 41.77; H, 1.40; M, 286.

***m*-(2,2-Dichloro-1-fluoroethenyl)fluorobenzene (6b).** a) **Via *m*-Fluorophenyllithium (4b).** To a Dry Ice–acetone cooled solution of *m*-bromofluorobenzene (98.4 g, 0.562 mol) in ether (100 ml) was added ethereal butyllithium (380 ml, 0.63 mol) while keeping the internal temperature between −30 °C and −40 °C. The resulting solution of **4b** was kept cold until its addition to an ice-cooled solution of **1** (121 g, 0.91 mol) in ether (100 ml) was started. The addition was conducted through a dropping funnel, briefly cooled with Dry Ice over 23 min while keeping the internal temperature of the reaction flask at about 20 °C. The resulting mixture was stirred for an additional 1 h, hydrolyzed, and worked up. Fractional distillation afforded **6b** (55.9 g, ÷0.98, 48%), bp 108 °C (28 mmHg).

b) **Via *m*-Fluorophenylmagnesium Bromide (5b).** A solution of *m*-fluorophenylmagnesium bromide (**5b**) was prepared from *m*-bromofluorobenzene (96.7 g, 0.552 mol) and magnesium (14.5 g, 0.60 g atom) in ether (300 ml). The addition of **1** (120 g, 0.90 mol) to the solution resulted in a mild refluxing, which lasted for 2 h. The resulting mixture was refluxed for an additional 16 h by external heating and hydrolyzed by pouring it onto a mixture of conc hydrochloric acid (50 ml) and crushed ice. The workup and fractional distillation afforded **6b** (92.2 g, ÷0.97, 82%), bp 111 °C(30 mmHg).

1-(2,2-Dichloro-1-fluoroethenyl)-2-(trifluoromethyl)benzene (6d). Ethereal butyllithium (330 ml, 0.55 mol) was added to a solution of *o*-bromo(trifluoromethyl)benzene (112.5 g, 0.500 mol) in ether (100 ml) over a period of 38 min below 7 °C (internal). The resulting solution was added to a Dry Ice–acetone cooled solution of **1** (105 g, 0.79 mol) in ether (100 ml) over 28 min while keeping the internal temperature at about −25 °C. The resulting mixture was allowed to warm to room temperature, refluxed for 1 h, and poured onto a mixture of crushed ice and concd hydrochloric acid (55 ml). The ether layer was separated, washed (with water and then with aq NaHCO$_3$), and dried (Na$_2$SO$_4$). Fractional distillation afforded **6d** (98.6 g, ÷0.98, 77%), bp 110 °C (30 mmHg), together with *o*-CF$_3$C$_6$H$_4$Cl (2.4 g, 3%), bp ca. 60 °C (30 mmHg).

1-(2,2-Dichloro-1-fluoroethenyl)-2,5-bis(trifluoromethyl)benzene (6h). A solution obtained by the addition of ethereal butyllithium (230 ml, 0.38 mol) to a solution of *p*-bis(trifluoromethly)benzene (63.8 g, 0.298 mol) in ether (100 ml) was refluxed for 4 h. It was then added to a Dry Ice–acetone cooled solution of **1** (90 g, 0.68 mol) in ether (100 ml) over 13 min while keeping the internal temperature between −20 °C and −30 °C. The resulting mixture was stirred for an additional 1 h without cooling and then poured onto a mixture of concd hydrochloric acid (40 ml) and crushed ice. The workup and fractional distillation afforded **6h** (69.3 g, ÷0.98, 72%), bp 96 °C(30 mmHg).

Lithiation of *m*-Bis(trifluoromethyl)benzene Followed by Treatment with Bromine. A solution (ca. 600 ml) of butyllithium prepared from 1.00 mol of butyl bromide was added to an ice-cooled solution of *m*-bis(trifluoromethyl)-

benzene (170 g, 0.794 mol) in ether (100 ml). Stirring and ice cooling were continued for 9 h. The reaction mixture was then cooled with Dry Ice–acetone, and bromine (165 g, 1.03 mol) was carefully added while the internal temperature was kept below −46 °C. The resulting mixture was rapidly warmed to 0 °C using a water bath, poured onto crushed ice; then aqueous sodium sulfite was added, and the whole mixture was thoroughly agitated in order to release butane. The ether layer was separated, washed with aqueous Na$_2$SO$_3$ and then with aqueous NaHCO$_3$, and dried with sodium sulfate. (The simultaneous use of NaHCO$_3$ and Na$_2$SO$_3$ was avoided since in a preliminary experiment, in which these reagents were used simultaneously, a portion of the (CF$_3$)$_2$C$_6$H$_3$Br was reduced to *m*-(CF$_3$)$_2$C$_6$H$_4$.) The solvent was removed, and the remaining liquid was fractionally distilled using a 50-cm metal-packed column at a high reflux ratio (mostly 60:1 or 120:1) until the solid product (**3i**) came out, which was rapidly collected by vacuum distillation. The following compounds were obtained: butyl bromide, 14.5 g (13.6%); *m*-bis(trifluoromethyl)benzene, bp ca. 113 °C, 21.1 g (12.7%); 1-bromo-3,5-bis(trifluoromethyl)benzene (**3j**), bp ca. 151 °C, 17.4 g (7.6%); 1-bromo-2,4-bis(trifluoromethyl)benzene (**3g**), bp 161.5 °C, 79.1 g (34.7%); 1-bromo-2,6-bis(trifluoromethyl)benzene (**3i**), bp 86 °C (29 mmHg) (bp ca. 173 °C), 70.9 g (31.1%). The above yields include individual compounds in mixed fractions, the calculation being based on the assumed proportionality of the weight to the GC peak area. The yields of essentially purely isolated **3g** and **3i** were 31% (70.9 g) and 29% (65.6 g), respectively. Compound **3j** was obtained at a purity of less than 88%. In another run, during which the time of the lithiation was extended to 24 h under otherwise the same conditions, the yields were as follows: butyl bromide, 3.6 g (3.4%); *m*-bis(trifluoromethyl)benzene, 8.4 g (5.1%); **3j**, 13.5 g (5.9%); **3g**,86.0 g (37.8%); **3i**,81.6 g (35.9%). The yields of essentially purely isolated **3g** and **3i** were 35% (80.1 g) and 34.5% (78.5 g), respectively.

3g: n_D^{20} 1.6363. ^{1}H NMR δ=7.60, (1H), 7.83 (1H), 7.92 (1H). The signals of the chemical shifts 7.60 and 7.83 seem to constitute an AB pattern (J=8 Hz) though the signal at 7.92 and the outer signal of the chemical shift 7.83 are unresolved. The signals of the chemical shift 7.83 show an additional splitting (d, J=2 Hz). ^{19}F NMR δ=15.33, 15.29 (partially resolved). Found: C, 32.58; H, 0.98; M$^+$, 292. Calcd for C$_8$H$_3$BrF$_6$: C, 32.79; H, 1.03; M, 292.

3i: Mp 51—52 °C, ^{1}H NMR δ=7.49 (1H), 7.81 (2H), J=ca. 8 Hz (results of approximate analysis as AB$_2$). ^{19}F NMR δ=16.2(s). Found: C, 32.55; H, 0.87; M$^+$, 292. Calcd for C$_8$H$_3$BrF$_6$: C, 32.79; H, 1.03; M, 292.

1-(2,2-Dichloro-1-fluoroethenyl)-2,6-bis(trifluoromethyl)benzene (6i). To an ice-cooled solution of 1-bromo-2,6-bis(trifluoromethyl)benzene (**3i**, 16.1 g, 0.055 mol) dissolved in a mixed solvent of ether (50 ml) and hexane (20 ml) was added a hexane solution of butyllithium (a 1.6 mol dm^{-3} Aldrich product, 37 ml, 0.059 mol) over 1 h. After a freshly prepared sample of **1** (19 g, 0.14 mol) was added to the solution, the resulting mixture was refluxed for a total of 15 h over two days and then hydrolyzed. Fractional distillation afforded **6i** (7.9 g, ÷0.91, 48%), bp 110 °C (30 mmHg). The minor products involved 1-chloro-2,6-bis(trifluoromethyl)benzene (**10i**, 1.1 g, 9%), bp ca. 70 °C (30 mmHg), and 1-(chloroethynyl)-2,6-bis(trifluoromethyl)-benzene (**13i**, 0.6 g, 4%), bp ca. 100 °C (30 mmHg). The latter

compound was contained in the first fractions of **6i**. Samples of **6i** containing **13i** are usable for the preparation of the corresponding acetylene **8i** since **13i** is the intermediate of the conversion of **6i** into **8i** (see the section of **8i**).

o-**Trifluoromethylphenylacetylene (8d).** To a Dry Ice-acetone cooled solution of **6d** (69.9 g, 0.27 mol) in ether (100 ml) was added butyllithium (380 ml, 0.63 mol) over 2 h while keeping the internal temperature below −50 °C. In GC monitoring, **6d** and *o*-CF₃C₆H₄C≡CCl were essentially absent. The resulting mixture was stirred for an additional 1.4 h without cooling and then hydrolyzed by pouring it onto a mixture of concd hydrochloric acid (65 ml) and cushed ice. The ether layer was washed (with water and then with aq NaHCO₃), dried (Na₂SO₄), and distilled, giving **8d** (38.5 g, ÷0.98, 86%), bp 68 °C(30 mmHg).

2,6-Bis(trifluoromethyl)phenylacetylene (8i). This particular run was conducted starting with a sample (43.0 g, 0.130 mol) consisting of 87.2% of **6i**, 9.9% of 2,6-(CF₃)₂-C₆H₃C≡CCl (**13i**), and 2.9% of impurities. The sample was dissolved in ether (50 ml) and treated (at about −50 °C) as above with ethereal butyllithium (200 ml, 0.334 mol). Compound **8i**, bp ca. 76 °C(29 mmHg), mp 56—57 °C, was obtained in 83% yield (24.8 g, ÷0.96).

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20) The tendency of disappearance of **4j** and **4g** was confirmed by the following experiment: Ethereal butyllithium (62 ml, 0.104 mol) was added to an ice-cooled solution of *m*-bis(trifluoromethyl)benzene (17.0 g, 0.079 mol) and undecane (internal standard, 5 ml) in ether (40 ml), and stirring and ice cooling were continued for 9 h. Then, with occassional monitoring, the resulting mixture was stirred for 24 h at ambient temperature (ca. 30 °C) and left standing for additional 24 h. In each case of monitoring, a 10 ml portion of the reaction mixture was transferred to a special vessel, diluted with ether, treated with bromine (2 g) under an inert atmosphere with Dry Ice–acetone cooling, and worked up. The GC peak areas changed as shown below, the peak area of *m*-(CF₃)₂C₆H₄ relative to that of undecane in the initial solution being taken as 100%. At 0 h (ca. 10 min after discontinuation of ice cooling), *n*-C₄H₉Br 8%, *m*-(CF₃)₂C₆H₄ 17%, **3j** 6%, **3g** 34%, **3i** 37%; at 3 h, *n*-C₄H₉Br 0%, *m*-(CF₃)₂C₆H₄ 12%, **3j** 5%, **3g** 38%, **3i** 38%; at 12 h, *m*-(CF₃)₂C₆H₄ 14%, **3j** 0%, **3g** 34%, **3i** 39%; at 24 h, *m*-(CF₃)₂C₆H₄ 18%, **3g** 19%, **3i** 38%; and at 48 h, *m*-(CF₃)₂C₆H₄ 22%, **3g** 4%, **3i** 38%. (Compound **4i** was unreactive to chlorotrimethylsilane, a reagent commonly used for monitoring organolithiums.)

21) Samples of **1** which were sealed soon after the preparation and have been stored at −20 °C may be used equally well.

22) The ¹⁹F chemical shifts given in this paper are measured downfield relative to external CF₃CO₂H although those given in Refs. 11 and 12 are measured upfield relative to the same standard.