

propyl iodide, 107-08-4; ethylbenzene, 100-41-4; *o*-xylene, 95-47-6; *m*-xylene, 108-38-3; *p*-xylene, 106-42-3; propylbenzene, 103-65-1; *o*-ethyltoluene, 611-14-3; *m*-ethyltoluene, 620-14-4; *p*-ethyltoluene, 622-96-8; isopropylbenzene, 98-82-8; *m*-*tert*-butyltoluene, 1075-38-3; *p*-*tert*-butyltoluene, 98-51-1; 3-methyl-*o*-xylene, 526-73-8; 4-methyl-*o*-xylene, 95-63-6; 5-methyl-*m*-xylene, 108-67-8; 5-ethyl-*m*-xylene, 934-74-7; 5-butyl-*m*-xylene, 98-19-1; toluene, 108-88-3; *tert*-butylbenzene, 98-06-6; anisole, 100-66-3; *N,N*-dimethylaniline, 121-69-7; 2,6-dimethylanisole, 1004-66-6; fluorobenzene, 462-06-6; iodobenzene, 591-50-4; tricarboxylchromium anisole, 12116-45-9; tri-

carbonylchromium *N,N*-dimethylaniline, 12109-10-3; tricarboxylchromium 2,6-dimethylanisole, 72207-21-7; tricarboxylchromium fluorobenzene, 12082-05-2; tricarboxylchromium iodobenzene, 12082-06-3; isopropyl iodide, 75-30-9; *tert*-butyl bromide, 507-19-7; *m*-ethyl-*tert*-butylbenzene, 14411-56-4; *p*-ethyl-*tert*-butylbenzene, 7364-19-4; *o*-fluorotoluene, 95-52-3; butylbenzene, 104-51-8; 2-methylanisole, 578-58-5; *o*-*N,N*-dimethyltoluidine, 609-72-3; *m*-*N,N*-dimethyltoluidine, 121-72-2; *p*-*N,N*-dimethyltoluidine, 99-97-8; tricarboxylchromium 1-ethyl-3,5-dimethylbenzene, 72207-22-8; tricarboxylchromium 1-butyl-3,5-dimethylbenzene, 72207-23-9.

Synthetic Applications of Metal Halides. Conversion of Cyclopropylmethanols into Homoallylic Halides

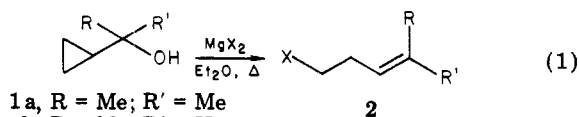
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Magnesium and beryllium halides in refluxing diethyl ether effect the transformation of cyclopropylmethanols into homoallylic halides, in contrast to several other metal halides and Lewis acid/nucleophile combinations which were examined. Magnesium bromide and iodide are particularly effective: conditions are mild, yields are high, and little or no byproducts are formed. Tertiary and benzylic alcohols are more reactive than secondary alcohols, while the latter are converted into *E* homoallylic halides with high stereoselectivity. Cyclopropylmethanol itself fails to react. In the cases of magnesium halide reactions with bicyclo[3.1.0]-2-hexanol and bicyclo[4.1.0]-2-heptanol, addition of an equimolar amount of zinc halide not only caused substantial rate enhancement but also increased regioselectivity.

The transformation of cyclopropylmethanols into homoallylic halides is a useful reaction which has received considerable development and synthetic application,¹ including incorporation into a basic set of reactions for a recent approach to computer-assisted synthesis.^{1k} To date, the most commonly used procedures involve treatment of the appropriate cyclopropylmethanol with 48% hydrobromic acid^{1a,c} or conversion of the alcohol into the corresponding bromide, followed by reaction with zinc bromide.^{1e,f} We have described briefly the use of magnesium halides to effect this transformation (eq 1) directly and



- 1 a, R = Me; R' = Me
 b, R = Me; R' = H
 c, R = H; R' = H
 d, R = Ph; R' = H
 e, R = Me; R' = Et

cleanly in good yields.² This method, which is related to chemistry reported by others,³ offers advantages over other

Table I. Treatment of 2-Cyclopropyl-2-propanol with Metal Halides and with Lewis Acid/Nucleophile Combinations^a

reagent/solvent ^b	reaction time, h (reflux)	% reaction ^c
MgI ₂ /Et ₂ O	4	100
MgBr ₂ /Et ₂ O	8	100
MgBr ₂ /THF	2	<4
MgCl ₂ /Et ₂ O ^d	71	95
CaCl ₂ /Et ₂ O ^d	16	0
CaBr ₂ /Et ₂ O ^d	48	<3
CaBr ₂ /THF ^d	24	<3
LiI/Et ₂ O	20	0
LiI/THF	36	<7
ZnBr ₂ /Et ₂ O	12	<1
BeCl ₂ /Et ₂ O	143	85
BeBr ₂ /Et ₂ O	45	95
CuSO ₄ /I ⁻ /Et ₂ O ^d	66	0
MgSO ₄ /I ⁻ /Et ₂ O ^d	52	0
CaCl ₂ /I ⁻ /Et ₂ O ^d	23	0

^a Reaction mixtures were sampled at regular intervals and examined by GC. ^b Iodide added as tetrabutylammonium iodide. ^c 2a was the only observed product; yields were determined by GC. ^d Heterogeneous reaction mixture.

procedures: intermediate cyclopropylmethyl halides need not be prepared, cyclobutyl compounds are not obtained as byproducts, and the use of strong mineral acids is avoided.⁴ We now report further on the possible synthetic scope and some mechanistic evidence regarding this transformation.

After initial experiments demonstrated that 2-cyclopropyl-2-propanol (1a) was converted cleanly into 5-

(1) (a) Julia, M.; Julia, S.; Guegan, R. *Bull. Soc. Chim. Fr.* 1960, 1072. (b) Hoffsommer, R. D.; Taub, D.; Wendler, N. L. *J. Org. Chem.* 1962, 27, 4134. (c) Julia, M.; Descoins, C.; Risse, C. *Tetrahedron Suppl.* 1966, 8, 443. (d) Sarel, S.; Yovell, J.; Sarel-Imber, M. *Angew. Chem., Int. Ed. Engl.* 1968, 7, 577. (e) Brady, S. F.; Ilton, M.; Johnson, W. S. *J. Am. Chem. Soc.* 1968, 90, 2882. (f) Johnson, W. S.; Li, T.; Faulkner, D. J.; Campbell, S. F. *Ibid.* 1968, 90, 6225. (g) Mori, K.; Ohki, M.; Sato, A.; Matsui, M. *Tetrahedron* 1972, 28, 3739. (h) Julia, M.; Paris, J.-M. *Tetrahedron Lett.* 1974, 3445. (i) Descoins, C.; Samain, D. *Ibid.* 1976, 745. (j) Santelli, C. *Ibid.* 1979, 1165. (k) Corey, E. J.; Long, A. K. *J. Org. Chem.* 1978, 43, 2208.

(2) McCormick, J. P.; Barton, D. L. *J. Chem. Soc., Chem. Commun.* 1975, 303.

(3) (a) Yovell, J.; Sarel-Imber, M.; Sarel, S. *Isr. J. Chem.* 1966, 4, 21p. (b) Coulomb, F.; Gore, J. *J. Organomet. Chem.* 1975, 87, C23. (c) Bieracki, W.; Gdula, A. *Synthesis* 1979, 37.

(4) For some aspects of these difficulties, see ref 1e.

Table II. Treatment of Alcohols with Magnesium Halides in Refluxing Diethyl Ether^a

reactants			products				
substr (mmol)	reagent (mmol)	T, h	struct	E/Z ratio	yield, ^b %	t _R ^c	ref
1a (1.8)	MgI ₂ (2.5)	4	2a, X = I		100	10.2	19
1a (1.0)	MgBr ₂ (1.2)	8	2a, X = Br		100	8.5	1a
1a (2.1)	MgCl ₂ (2.5)	71	2a, X = Cl		95	4.6	19
1b (1.6)	MgI ₂ (2.6)	91	2b, X = I	94/6	95	8.6/7.8	
1b (1.2)	MgBr ₂ (1.4)	193	2b, X = Br	93/7	90	4.0/3.2	21
1c (9.8)	MgI ₂ (12.0)	72	2c, X = I		0		
1d (1.0)	MgI ₂ (1.2)	13	2d, X = I	95/5	100	20.5/18.5	
1d (2.4)	MgBr ₂ (3.3)	3	2d, X = Br	98/2	100	18.8/17.5	22
1d (6.8)	MgCl ₂ (7.0)	51	2d, X = Cl	98/2	74	12.8/11.7	23
1e (1.0)	MgI ₂ (1.2)	4	2e, X = I	75/25	100	12.0	
1e (2.0)	MgBr ₂ (2.5)	8	2e, X = Br	75/25	95	10.5	24
1-phenylethanol (0.8)	MgI ₂ (2.2)	30	1-phenyl-1-iodoethane		0		

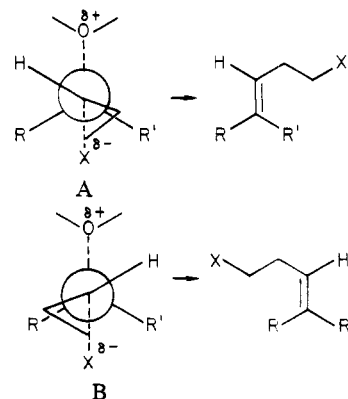
^a Reaction mixtures were sampled at regular intervals and examined by GC. ^b Determined by GC. ^c Retention time in minutes. Column: 1/8 in. × 6 ft, 4% OV-101 on high performance Chromosorb G. Temperature: 50 °C rising to 200 °C at 10 °C/min. Retention times of isomers are given as E/Z.

iodo-2-methyl-2-pentene by magnesium iodide in refluxing diethyl ether, further investigation with respect to both reagent and substrate was carried out. To assess the generality of such action of metal halides, 1a was treated with a variety of metal halides and Lewis acid/nucleophile combinations (Table I). Of the several agents examined, only magnesium bromide and iodide, compounds which are readily available and do not suffer from the expense and toxicity disadvantages of the beryllium halides, surfaced as practical reagents which afford high yields of the homoallylic halides under mild, convenient conditions. In contrast to other procedures, such as use of HBr, which commonly afford undesirable mixtures, including cyclobutyl and cyclopropyl byproducts,⁴ these reagents were found to form only the desired halides except where otherwise noted. Magnesium chloride, however, was much less reactive and, in keeping with its greater acidity, upon reaction with 1d caused dehydration to the ether (28%) in addition to formation of expected halide 2d (51%) and a second, unidentified byproduct (13%), as revealed by GC analysis. With respect to synthetic limitations of these reagents, it is noteworthy that in tetrahydrofuran the reaction using magnesium bromide is markedly slower and fails when magnesium iodide is used. Apparently, in tetrahydrofuran, magnesium iodide is either insoluble or, more likely, forms an insoluble complex. Along this same line, the lack of reactivity of some reagents examined (noted in Table I as heterogeneous reaction mixtures) may be due to the lack of solubility in anhydrous ether.

As exemplified by the reactivity of compounds 1a-e (Table II), cyclopropylmethanols were found to be generally susceptible to rearrangement of equimolar amounts of magnesium bromide or iodide in refluxing diethyl ether. The tertiary and benzylic systems were particularly reactive. On the other hand, cyclopropylmethanol itself did not react at an appreciable rate. As well, potentially reactive alcohols such as benzyl alcohol and 1-phenylethanol were recovered unchanged after treatment with magnesium iodide in refluxing diethyl ether for extended periods, in contrast to a report that the tosylate of the latter alcohol is converted into the corresponding iodide by this reagent.⁵ The cyclopropyl ring clearly plays a role in substrate reactivity.

The stereochemical outcome, where *E* and *Z* isomers exist, appears to follow the relative stabilities of these isomers. In the disubstituted cases, the stereoselectivity

for the *E* isomer is high,⁶ while trisubstituted olefins can be expected to form in a ratio more nearly approximating the 3:1 ratio observed for 2e.⁷ This latter result was determined by GC and NMR (¹H and ¹³C) analyses of the methylhexenes, obtained by lithium aluminum hydride reduction of 2e, in comparison with a known mixture of these alkenes.⁸ These results can be understood on the basis of analysis of the geometries of proposed^{1e} transition states for this type of rearrangement. Of the two conformational possibilities which permit an antiperiplanar arrangement of bonds being made and broken, conformation A would clearly be favored for the secondary al-



cohols (1, R = alkyl or aryl, R' = H), leading to predominant formation of the *E* isomer. However, for the tertiary alcohols such as 1e (R = Et, R' = Me), conformation A would be favored over B to a smaller extent, giving rise to lower stereoselectivity.

Additional results provide information regarding the rate-determining step which may be of value in assessment of synthetic potential. Development of positive charge, as suggested by the relative reactivities of 1a-e (Table II), was more clearly demonstrated by competition experiments. The relative reactivities of an equimolar mixture of 1d and 1b were found to be 24:1 with magnesium iodide and 55:1 with magnesium bromide. Importance of nucleophile involvement is suggested by the general order of rates with the three magnesium halides, an order which

(6) Similar results have been reported: Julia, M.; Julia, S.; Tchen, S. *Bull. Soc. Chim. Fr.* 1961, 1849.

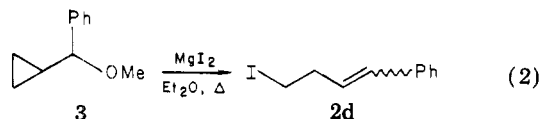
(7) For comparable stereochemical results, see ref 1c and references therein.

(8) (a) Obtained by Wittig reaction of *n*-propyltriphenylphosphorane with 2-butanone. (b) de Haan, J. W.; van de Ven, L. J. M. *Org. Magn. Reson.* 1973, 5, 147.

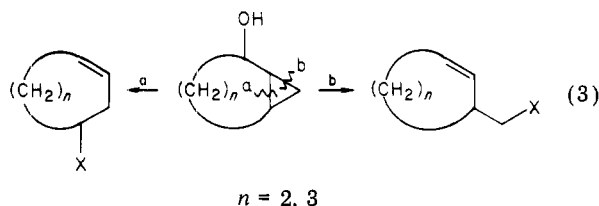
(5) Gore, J.; Place, P.; Roumestant, M. L. *J. Chem. Soc., Chem. Commun.* 1973, 821.

parallels relative nucleophilicities of the halides but is contrary to the probable relative acidity of the reagents. However, lack of involvement of external nucleophile was indicated by carrying out the reaction of magnesium iodide with 1-cyclopropylethanol (**1b**) in the presence of tetrabutylammonium iodide (1 molar equiv): no rate enhancement was observed.

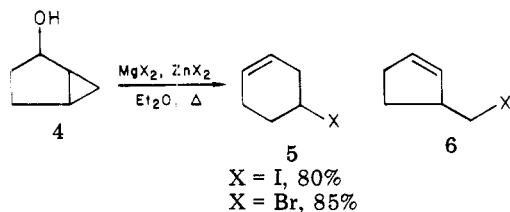
Interestingly, substitution of alkoxy functionality for hydroxy did not preclude reaction: the methyl ether (**3**) of cyclopropylphenylmethanol was transformed into **2d** ($X = I$), formed in the same 95:5 *E/Z* ratio as obtained from **1d** by magnesium iodide (eq 2), although at a rate substantially slower than that of the corresponding alcohol (**1d**). This indicates that hydrogen halide is not required for this reaction.



For further investigation of the potential of this reaction, the bicyclic [3.1.0]hexane and [4.1.0]heptane systems were studied. The results reveal that the combination of magnesium halide and zinc halide provides a striking increase in both reaction rate and regioselectivity. These bicyclic systems present the possibilities of bond cleavage to give ring-expanded cyclic halides (path a, eq 3) and alternative bond cleavage to give halomethyl products (path b, eq 3).



Bicyclo[3.1.0]-2-hexanol (**4**), as a 9:1 mixture of *cis* and *trans* isomers, proved to be rather unreactive toward magnesium halides: in refluxing diethyl ether the amounts of starting material depletion were 10% (92 h), 25% (122 h), and 0% (47 h) for treatment with magnesium iodide, bromide, and chloride, respectively. However, the use of approximately 1 molar equiv of magnesium iodide together with 1 molar equiv of zinc iodide effected, after 72 h, 87% conversion of **4** into a mixture of two products, the major



(80%) compound being 4-iodocyclohexene. Likewise, use of molar equivalents of magnesium bromide and zinc bromide gave, after 216 h, 95% conversion of **4** into a two-product mixture (by GC analysis), 85% of which proved to be 4-bromocyclohexene. In both cases, the minor product was not identified but probably was not the 3-(halomethyl)cyclopentene (**6**).

The results for the magnesium halide ring opening of bicyclo[4.1.0]-2-heptanol (**7**) with and without zinc halide are presented in Table III. In this system, zinc halide not only has a rate-accelerating effect but also serves to direct the regiochemistry to permit complete selectivity for (halomethyl)cyclohexene **9** (see Table III) in the bromide and iodide cases. The contrast in rate behavior and re-

Table III. Treatment of *cis*-Bicyclo[4.1.0]-2-heptanol with Magnesium and Zinc Halides in Refluxing Diethyl Ether^a

reagent	<i>t</i> , h	% conversion	rel percentages	
			8	9
MgCl ₂	166	95	70	30
MgCl ₂ /ZnCl ₂	70	100	40	60
MgBr ₂	79	75	40	60
MgBr ₂ /ZnBr ₂	22	98	0	100
MgI ₂	18	81	17	83
MgI ₂ /ZnI ₂	4	98	0	100

^a Reaction mixtures were sampled at regular intervals and examined by GC.

giochemical outcome for the [3.1.0] and [4.1.0] systems is presumably the result of specific geometric factors. The preferential opening by magnesium chloride, the strongest Lewis acid of the three reagents, of **7** to give **8** (path a) is similar to results reported for perchloric acid ring opening of the [4.1.0] system.⁹ The contrasting exclusive formation of (halomethyl)cyclohexenes **9** by magnesium bromide (or iodide) acting together with the corresponding zinc halide may be in part due to effects of the latter on **8**. Treatment of a 2:3 mixture of **8** and **9** ($X = Br$) with zinc bromide alone in refluxing diethyl ether effected complete isomerization of **8** into **9**, while magnesium bromide alone was found to have no effect. In this regard, apparently zinc bromide does not effect isomerization of acyclic homoallylic bromides.^{1e} As well, zinc halides were found to be unreactive by themselves with cyclopropylmethanols under the conditions of the reaction.

Understanding of the mechanistic basis of these effects, particularly rate enhancement, of added zinc halides await further evidence. However, it is perhaps worth noting that examples of dramatic effects of metal halides acting together with other reagents are known. In particular, these include use of magnesium halides to promote Grignard reactions¹⁰ and even to direct the course of Grignard reactions.^{3b,11}

Experimental Section

The instruments used for reported data were as follows: IR, Perkin-Elmer 237-B grating spectrophotometer; proton NMR, either a Varian A-60 or a Varian T-60 spectrometer (tetramethylsilane as an internal standard); ¹³C NMR, Bruker HX-90 spectrometer; melting points (uncorrected), Thomas-Hoover apparatus; GC, Varian-Aerograph Model 2440 with flame-ionization detectors (unless otherwise indicated, a 1/8 in. × 6 ft, 4% OV-101 on high-performance Chromosorb G column was used, with temperature programming from 50 to 200 °C at 10 °C/min); mass spectra, Du Pont 21-490 interfaced with a Varian-Aerograph Model 1400 GC with a flame-ionization detector and a 1/8 in. × 4 ft, 3% SE-30 on Varapack no. 30 column. Silica gel used was as follows: Merck HF_{254/366} (for TLC; compounds were visualized with iodine or sulfuric acid charring); Merck PF₂₅₄ (for column chromatography). Elemental analyses were performed by Galbraith Laboratories.

Metal Halides. Anhydrous LiI, ZnI₂, CaBr₂, and CuCl₂ were obtained from the Ventron Corp., MgCl₂, BeBr₂, and BeCl₂ were obtained from Cerac/Pure, and ZnBr₂ was purchased from Fisher Scientific.

(9) Friedrich, E. C.; Cooper, J. D. *Tetrahedron Lett.* 1976, 4397.

(10) For example, see: Mukaiyama, T.; Yamaguchi, M.; Narasaka, K. *Chem. Lett.* 1978, 689.

(11) Coulomb-Delbecq, F.; Gore, J. *Bull. Soc. Chim. Fr.* 1976, 541.

Magnesium iodide, as an anhydrous diethyl ether solution (concentration determined by EDTA titration of magnesium ion), was prepared from Mg and HgI_2 .¹² Solutions prepared in this manner were more stable than those prepared by reaction of Mg and I_2 .

Magnesium bromide, as an anhydrous diethyl ether solution (concentration determined by EDTA titration of magnesium ion), was obtained by reaction of 1,2-dibromoethane with excess Mg, followed by filtration.

Cyclopropylmethanols. The required alcohols were either purchased from Aldrich or prepared by known methods. In all cases, the spectral and physical properties were in accord with structural assignments and available literature data.

Standard Procedures for Reaction of Cyclopropylmethanols with Metal Halides. To a three-necked flask fitted with a condenser, stir bar, and nitrogen line were added the appropriate amounts of metal halide(s) and anhydrous solvent. The metal halide was introduced as an ethereal solution by syringe in the cases of MgI_2 or MgBr_2 or as a solid weighed in a glovebag when other air- and moisture-sensitive metal halides were used. The compound to be treated was then introduced, dissolved in the appropriate anhydrous solvent. When necessary, samples were withdrawn under a stream of nitrogen. Workup procedures for the iodides consisted of washing the organic solution with two portions of 10% sodium thiosulfate solution and one portion of saturated sodium chloride solution. The other halides were worked up by washing with two portions of water followed by one portion of saturated sodium chloride solution. The organic layer was then dried (MgSO_4), and the solvent was removed. Any important differences or changes in this procedure are noted.

Determination of the Z/E Ratio of 1-Halo-4-methyl-3-hexenes (2e) Obtained from 2-Cyclopropyl-2-butanol (1e). To 0.181 g (0.81 mmol) of 1-iodo-4-methyl-3-hexene (2e, X = I), obtained in 84% isolated yield from 1e in 15 mL of anhydrous diethyl ether was added 0.035 g (0.93 mmol) of LiAlH_4 . After the mixture was refluxed for 14 h, standard aqueous workup afforded an ethereal solution of 3-methyl-3-hexene with a Z/E isomer ratio of 1:3 (by GC, 50 °C).

Similar treatment of 0.136 g (76.8 mmol) of 1-bromo-4-methyl-3-hexene (2e, X = Br), obtained in 75% isolated yield from 1e) gave a 1:3 Z/E mixture of 3-methyl-3-hexene in ether, as above.

Preparation of an authentic mixture of (Z)- and (E)-3-methyl-3-hexenes by using a standard Wittig reaction^{9a} gave after distillation a 3:2 Z/E mixture: GC (50 °C, isothermal) retention times 8.6, 9.3 min (3:2, respectively); bp 87–88 °C; NMR (neat) 0.93, 0.96 ppm (2 t, 6, J = 7 Hz, CH_3CH_2), 1.51, 1.56 (2 d, 3, J = 2 Hz, $\text{CH}_2\text{C}=\text{C}$); 1.56-ppm signal, Z isomer, larger), 1.8–2.4 (m, 4, $\text{CH}_2\text{C}=\text{CHCH}_2$), 5.11 (t, 1, J = 7 Hz, $\text{C}=\text{CH}$); ¹³C NMR (CCl_4 , in parts per million relative to Me_4Si) for Z isomer (larger signals) 12.60 (C-1), 24.47 (C-2), 135.59 (C-3), 126.10 (C-4), 20.69 (C-5), 14.54 (C-6), 22.63 (C-7); for E isomer 12.60 (C-1), 32.13 (C-2), 135.59 (C-3), 124.92 (C-4), 20.91 (C-5), 14.22 (C-6), 15.51 (C-7); stereochemical assignments based on ¹³C NMR data corresponded with literature data.^{8b}

4-Iodocyclohexene (5, X = I) from Bicyclo[3.1.0]-2-hexanol (4). By use of the standard procedure, bicyclic alcohol 4 (as a 9:1 mixture of cis and trans isomers)¹³ was 90% unchanged upon treatment with MgI_2 for 92 h. The two products (by GC) were not isolated.

Similar treatment of 0.199 g (2.03 mmol) of 4 with 2.2 mmol of MgI_2 and 0.600 g (1.87 mmol) of ZnI_2 for 72 h gave 87% (by GC) conversion of 4 into two products (1:4 ratio, retention times 7.5 and 7.7 min). After filtration through alumina (activity III, 10 g, pentane eluant), 0.162 g (38%, material loss due to volatility) was obtained, still as a 1:4 mixture, the major product being 4-iodocyclohexene.¹⁴

4-Bromocyclohexene (5, X = Br) from Bicyclo[3.1.0]-2-hexanol (4). By use of the standard procedure, 4 (9:1, cis/trans) was 75% unchanged after treatment for 122 h with MgBr_2 . The two products (by GC) were not isolated.

Similar treatment of 0.201 g (2.05 mmol) of 4 with 2.33 mmol of MgBr_2 and 0.567 g (2.76 mmol) of ZnBr_2 for 216 h effected 95%

conversion of 4 into two products (by GC, retention times 6.0, 6.4 min) in a ratio of 15:85, respectively. Removal of solvent and filtration of the residue through alumina (activity III, 2 g, pentane eluant) gave 18 mg (loss owing to volatility) of two isomers, primarily 4-bromocyclohexene.¹⁴

3-(Iodomethyl)cyclohexene (9, X = I) and 4-Iodocycloheptane (8, X = I) from Bicyclo[4.1.0]-2-heptanol (7). Treatment of 0.114 g (1.02 mmol) of alcohol 7¹⁵ with 1.7 mmol of MgI_2 using the standard procedure for 18 h gave after aqueous workup 0.181 g (0.82 mmol, 81%) of a clear, yellow liquid composed of 9 (X = I) and 8 (X = I)²⁵ in a 83:17 ratio (GC, 4% OV-17, 100 °C, retention times 37.5 and 40.5 min) with no 7 present.

By use of the standard procedure, treatment for 4 h of 0.209 g (1.86 mmol) of 7 with 2.0 mmol of MgI_2 and 0.591 g (1.85 mmol) of ZnI_2 gave after aqueous workup 0.406 g (98%) of 9 (X = I).

Anal. Calcd for $\text{C}_7\text{H}_{11}\text{I}$: C, 37.86; H, 4.99. Found: C, 38.03; H, 5.04.

3-(Bromomethyl)cyclohexene (9, X = Br)¹⁶ and 4-Bromocycloheptene (8, X = Br)¹⁷ from Bicyclo[4.1.0]-2-heptanol (7). By use of the standard procedure, treatment for 79 h of 1.20 g (10 mmol) of 7 with 12.1 mmol of MgBr_2 gave after aqueous workup 1.31 g (75%) of a 9/8 mixture (X = Br) in a 3:2 ratio by GC (4% OV-17, 100 °C, retention times 15 and 16 min). Preparative GC separation allowed characterization.

Similar treatment of 0.141 g (1.26 mmol) of 7 with 1.3 mmol of MgBr_2 and 0.395 g (1.76 mmol) of ZnBr_2 for 19 h gave 98% conversion into 9 (X = Br); no 8 (X = Br) could be detected.

Anal. Calcd for $\text{C}_7\text{H}_{11}\text{Br}$ (mixture of 8 and 9): C, 48.03; H, 6.33. Found: C, 48.20; H, 6.51.

3-(Chloromethyl)cyclohexene (9, X = Cl) and 4-Chlorocycloheptene (8, X = Cl) from Bicyclo[4.1.0]-2-heptanol (7). By use of the standard procedure, treatment for 166 h of 0.142 g (1.27 mmol) of alcohol 7 with 0.151 g (1.59 mmol) of MgCl_2 (as a suspension) resulted in 95% conversion (GC analysis), 80% of which was a ca. 3:7 mixture of 9 and 8 (X = Cl) as determined by NMR: 2.61 (m, $\text{C}=\text{CHCH}_2\text{CHCl}$ of 8), 4.04 (m, CHCl of 8), 3.42 ppm (d, CH_2Cl of 9); mass spectrum on the mixture (70 eV), m/e (relative intensity) 132 (8), 130 (24), 95 (27), 94 (35), 81 (80), 79 (100), 67 (36), 55 (13), 53 (28), 41 (30).

Similar treatment for 42 h of 0.124 g (1.11 mmol) of alcohol 7 with 0.125 g (1.31 mmol) of MgCl_2 and 0.179 g (1.01 mmol) ZnCl_2 effected complete conversion into products, 90% of which was a 3:2 mixture (by NMR) of 9 (X = Cl) and 8 (X = Cl).

Treatment of 3-(Bromomethyl)cyclohexene (9, X = Br) and 4-Bromocycloheptene (8, X = Br) with Zinc Bromide and with Magnesium Bromide Separately. By use of the standard procedure, 0.351 g (2.00 mmol) of a 3:2 mixture of 9 and 8 (X = Br) was treated for 23 h with 0.535 g (2.36 mmol) of ZnBr_2 . By GC, 9 (X = Br) was the only substance present. Aqueous workup afforded 0.321 g (92%) of material, confirmed by NMR to be only 9 (X = Br).

Similar treatment using MgBr_2 in place of ZnBr_2 did not affect the ratio of 9 to 8 (X = Br) after 24 h.

Cyclopropylmethoxyphenylmethane (3). To a 10-mL flask were added 0.758 g (5.12 mmol) of cyclopropylphenylmethanol (1d), 2 mL of hexane, 10 mg of Bu_4NI , and 0.6 mL (ca. 13 mmol) of 50% NaOH solution. This was stirred rapidly for 30 min with the formation of a precipitate. To the alkoxide was added with stirring and cooling (ice bath) 0.71 mL (0.95 g, 7.5 mmol) of dimethyl sulfate over a period of 1 h. The reaction mixture was stirred at room temperature for 3 h, 0.2 mL of concentrated NH_4OH solution was added, and the mixture was stirred for 30 min at room temperature. Aqueous workup gave 0.698 g of crude ether 3. Column chromatography (78 g of silica gel, 5% diethyl ether/hexane) yielded 0.595 g (72%) of 3:¹⁸ 99% pure by GC;

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TLC (5% diethyl ether/hexane) R_f 0.22 (product), 0.04 (starting material reference); IR (neat) no OH, 1090 cm^{-1} (C-O); NMR (neat) 0.2-0.4 (m, 4, CH_2CH_2), 0.8-1.25 (m, 1, CH of cyclopropyl group), 3.08 (s, 3, CH_3), 3.59 (d, 1, $J = 6$ Hz, CHO), and 7.2 ppm (br s, 5, aromatic H).

Anal. Calcd for $\text{C}_{11}\text{H}_{14}\text{O}$: C, 81.44; H, 8.69. Found: C, 81.54; H, 8.76.

Treatment of Cyclopropylmethoxyphenylmethane (3) with Magnesium Iodide in Diethyl Ether. By use of the standard procedure 0.157 g (0.97 mmol) of ether 3 was treated with 0.640 g (2.3 mmol) of MgI_2 in diethyl ether. After 127 h at reflux, 3 was 70% converted into 2d (1:24 Z/E by GC, retention times 15.9 and 16.6 min, 11.6 min for 3). Workup afforded 0.243 g of a mixture of iodides 2d, together with some 3 (by NMR).

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Registry No. 1a, 930-39-2; 1b, 765-42-4; 1c, 2516-33-8; 1d, 31729-66-5; 1e, 4435-58-9; 2a (X = Br), 2270-59-9; 2a (X = Cl), 7712-60-9; 2a (X = I), 43161-11-1; (E)-2b (X = I), 56399-98-5; (Z)-2b (X = I), 66688-64-0; (E)-2b (X = Br), 7515-62-0; (Z)-2b (X = Br), 50273-84-2; 2c (X = I), 7766-51-0; (E)-2d (X = I), 56399-99-6; (Z)-2d (X = I), 73611-77-5; (E)-2d (X = Br), 7515-41-5; (Z)-2d (X = Br), 73611-78-6; (E)-2d (X = Cl), 7515-46-0; (Z)-2d (X = Cl), 35123-84-3; (E)-2e (X = Br), 51861-86-0; (Z)-2e (X = Br), 38351-81-4; (E)-2e (X = I), 56400-00-1; (Z)-2e (X = I), 56400-01-2; 3, 5558-08-7; *cis*-4, 822-58-2; *trans*-4, 822-59-3; 5 (X = Br), 3540-84-9; 5 (X = I), 2566-56-5; 7, 7432-49-7; 8 (X = Br), 73611-79-7; 8 (X = Cl), 32446-16-5; 8 (X = I), 62914-11-8; 9 (X = Br), 34825-93-9; 9 (X = Cl), 19509-49-0; 9 (X = I), 34825-94-0; magnesium iodide, 10377-58-9; magnesium bromide, 7789-48-2; 1-phenylethanol, 98-85-1; 1-phenyl-1-iodoethane, 10604-60-1.

Supplementary Material Available: Spectral and analytical data for the homoallylic halides 2a-e shown in Table II. IR, NMR, and mass spectral data for 5 (X = Br, I), 8 (X = Br, I), and 9 (X = Br, I) (3 pages). Ordering information is given on any current masthead page.

Alkyl Nitrite-Metal Halide Deamination Reactions. 7. Synthetic Coupling of Electrophilic Bromination with Substitutive Deamination for Selective Synthesis of Multiply Brominated Aromatic Compounds from Arylamines^{1a}

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Aromatic amines undergo oxidative substitution with copper(II) bromide that is in competition with substitutive deamination when these reactions are performed with *tert*-butyl nitrite. Except for the exceptionally reactive 4-substituted 1-aminonaphthalenes, which undergo selective bromine substitution at the 1- and 2-positions in relatively high isolated yields, rates for oxidative bromination and substitutive deamination are not sufficiently different that selective multiple bromination can be achieved. Oxidative bromination of *N,N*-dimethylaniline by copper(II) bromide occurs with partial dealkylation, and nitration products are observed from reactions performed with copper(II) bromide and *tert*-butyl nitrite. Implications of these results for the successful utilization of copper(II) bromide/*tert*-butyl nitrite combinations in substitutive deamination reactions of aromatic amines are discussed. Multiply brominated aromatic compounds are produced from aromatic amines in high yield through treatment of the aromatic amine with the combination of molecular bromine and catalytic quantities of copper(II) bromide and, following a normally brief time delay, with *tert*-butyl nitrite. All unsubstituted aromatic ring positions ortho and para to the amino group, as well as the position of the amino group, are substituted by bromine. The only observed byproducts from use of this procedure (usually $\leq 2\%$ yield) are the partially brominated benzene derivatives.

We have recently reported that di- and tribromoarenes are formed as byproducts during nitrosative substitution reactions of arylamines with *tert*-butyl nitrite and copper(II) bromide in acetonitrile.² Although relatively low yields of these products were described, the uniqueness of this process in methodologies for the Sandmeyer reaction,^{3,4} the observed orientation of bromine substitution

ortho and/or para to the original position of the amino group, apparently independent of the activating influence of a spectrum of para-substituted ring substituents, and the potential suggested by these observations for directed multiple bromination of arylamines prompted this investigation.

The amino group has long been recognized for its pronounced directive influence in electrophilic halogenation reactions.⁵ When electrophilic halogenation is coupled to the Sandmeyer reaction, directed multiple halogenation can be achieved (e.g., eq 1). However, such processes generally require a minimum of three sequential reactions and are subject to the experimental limitations of each reaction.⁶ In this paper we report an efficient direct

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