consumed): bp 128–128.5°; $n^{25}D$ 1.4203 (vpc bp 125.5°); infrared bands at 1750 (F_2C=C), 3100, 200–1600, 1500, 1450 (phenyl), and 1270–1100 (CF) cm^{-1}.

Anal. Calcd for $C_9H_8F_5$: C, 51.93; H, 2.42; F, 45.64. Found: C, 51.58; H, 2.40; F, 45.22.

Acknowledgment.—The investigation by nmr techniques of the structures of many of the compounds described in this paper was carried out by Mr. Donald W. Moore, Research Department, U. S. Naval Ordnance Test Station, China Lake, California, for which we are grateful. This research was financially supported by the Naval Bureau of Weapons, Project No. RRMA-03-065/216-1/R007-03-01, J. J. Gurtowski, Project Engineer.

Friedel–Crafts Reactions of Amino Tertiary Alcohols[1a]

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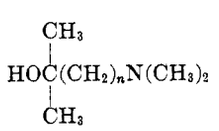
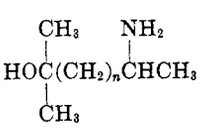
ω-Arylalkylamines are prepared in generally good yield by the Friedel–Crafts reactions of amino tertiary alcohols with *o*-xylene, naphthalene, veratrole, thiophene, and benzo[*b*]thiophene. In every case one isomer predominates to the extent of 95% or greater. Dimethylamino-2-methyl-2-propanol gives Friedel–Crafts products as well with toluene, 1- and 2-chloronaphthalene, and 1,5- and 2,3-dimethylnaphthalene, but not with veratrole, thiophene, or benzothiophene.

The Friedel–Crafts reactions of amino tertiary alcohols provide a satisfactory and fairly general method for preparing ω-arylalkylamines. The aluminum chloride promoted condensation of various amino *t*-butyl alcohols (1,2-amino alcohols) with benzene was first reported by Suter and Ruddy in 1943;[2] we have found that 1,3-, 1,4-, and 1,5-amino tertiary alcohols as well can, under rather specific conditions, be induced to condense with a variety of aromatic compounds in generally excellent yield.

The amino alcohols used have all been described previously: dimethylamino-2-methyl-2-propanol (**1**),[3] 4-dimethylamino-2-methyl-2-butanol (**2**),[3] 4-amino-2-methyl-2-pentanol (**3**),[4] 5-dimethylamino-2-methyl-2-pentanol (**4**),[3] 6-dimethylamino-2-methyl-2-hexanol (**5**),[3] and 6-amino-2-methyl-2-heptanol (**6**). Aromatic substrates were *o*-xylene, naphthalene, veratrole, thiophene, and benzo[*b*]thiophene, and in each product one isomer predominated to the extent of 95% or greater. The 1,2-amino alcohol **1** gave Friedel–Crafts products as well with toluene, 1- and 2-chloronaphthalene, and 1,5- and 2,3-dimethylnaphthalene, but not with veratrole, thiophene, or benzothiophene.

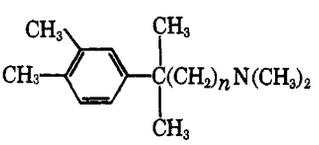


1, $n = 1$
2, $n = 2$
4, $n = 3$
5, $n = 4$

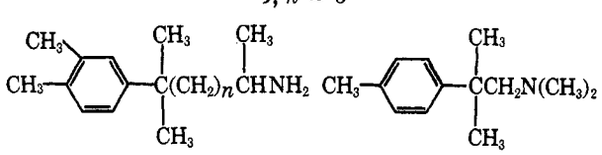


3, $n = 1$
6, $n = 3$

Reactions with *o*-xylene were carried out in nitrobenzene using a 2.5:1 mole ratio of aluminum chloride to amino alcohol. The product was in each instance almost exclusively the 4 isomer **8–10**. Structures were established by means of the strong, low-frequency infrared bands (725, 820, and 880 cm^{-1}) characteristic of 1,2,4 substitution and present in the spectrum of 3,4-dimethyl-*t*-butylbenzene.[5] With *o*-xylene as solvent the 1,2-amino alcohol **1** also gave the 4 isomer **7**, and with toluene the product was the *para* isomer **11** (ν_{max} 810 cm^{-1}).



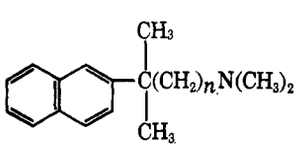
7, $n = 1$
9, $n = 3$



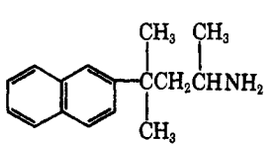
8, $n = 1$
10, $n = 3$

11

The reaction with naphthalene also utilized aluminum chloride in nitrobenzene (cyclohexane for the 1,2-amino alcohol), yielding in each case the β isomer **12–15**. The low-frequency infrared pattern for each (750, 820, 855, and 890 cm^{-1}) was nearly identical with that of β-*t*-butylnaphthalene.[6]



12, $n = 1$
14, $n = 3$
15, $n = 4$



13

For veratrole, anhydrous hydrogen fluoride was the only satisfactory condensation medium found. Again, the 4 isomer was the exclusive product (**16–18**), identified by the characteristic low-frequency infrared spectrum (770, 810, and 855 cm^{-1}), similar to that of 3-hydroxy-4-methoxy- and 4-hydroxy-3-methoxy-*t*-butylbenzene.[7]

(1) (a) Supported by Merck Sharp and Dohme Research Laboratories. (b) Inquiries may be addressed to W. D. B.: U. S. Army Natick Laboratories, Natick, Mass.

(2) C. M. Suter and A. W. Ruddy, *J. Am. Chem. Soc.*, **65**, 762 (1943).

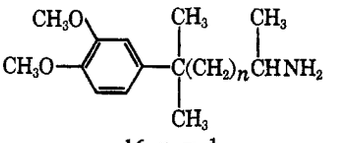
(3) B. K. Campbell and K. N. Campbell, *ibid.*, **60**, 1372 (1938).

(4) J. English, Jr., and K. D. Bliss, *ibid.*, **78**, 4057 (1956).

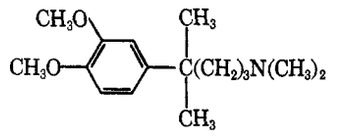
(5) "The Sadtler Standard Spectra," Midget ed, Sadtler Research Laboratories, Philadelphia, Pa., Spectrum No. 5335.

(6) Reference 5, Spectrum No. 8153.

(7) R. H. Rosenwald, *J. Am. Chem. Soc.*, **74**, 4062 (1953).



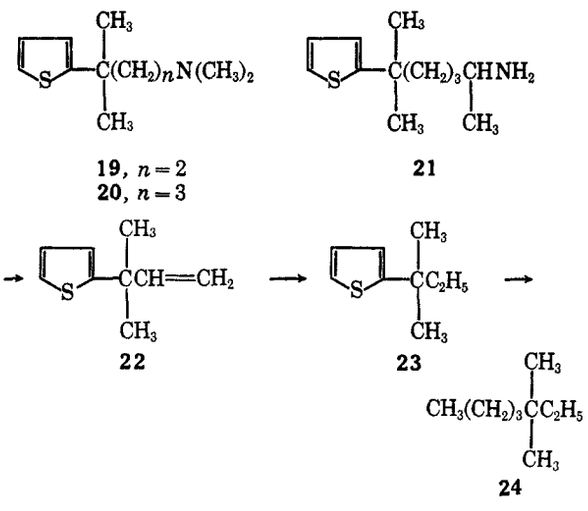
16, $n = 1$
18, $n = 3$



17

Of the Friedel–Crafts reagents we investigated only stannic chloride in nitrobenzene effected condensation of amino alcohols with thiophene, and then only in fair to poor yield. The 1,3-type primary amino alcohol **3** failed to give a product at all; **2** was used instead. That substitution occurred in the α position (**19–21**, Scheme I) was established for the 1,3 product **19** by

SCHEME I



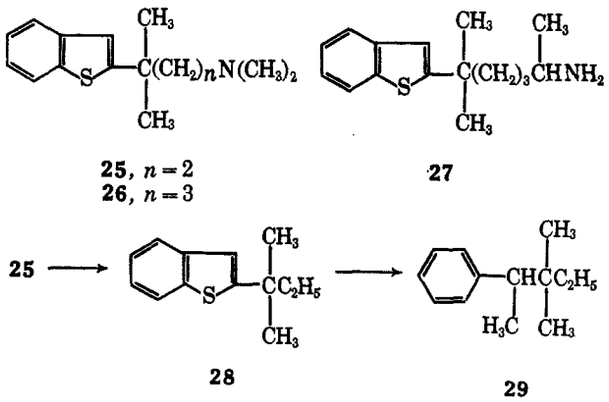
degradation. Hofmann exhaustive methylation gave the unsaturated thiophene derivative **22** which was reduced to 2-*t*-amylthiophene **23**, identical with material prepared from *t*-amyl alcohol and thiophene. Although 2-*t*-amylthiophene had been reported previously,[8] it seemed advisable to establish its structure rigorously. Desulfuration with Raney nickel catalyst gave 3,3-dimethylheptane (**24**), identical by mass spectrum with the synthetic hydrocarbon.[9] The 1,4 (**20**) and 1,5 products (**21**) have infrared spectra in the long wavelength region nearly identical with those of 2-*t*-amylthiophene and **19** (655, 690, 780, 820, and 850 cm^{-1}).

Benzo[*b*]thiophene underwent β substitution (**25–27**, Scheme II). Hofmann exhaustive methylation and reduction of the 1,3 product **25** gave 3-*t*-amylbenzothiophene (**28**), identical with the Friedel–Crafts product of *t*-amyl alcohol and benzothiophene. Desulfuration of **28** gave α,β,β-trimethylbutylbenzene (**29**), identical by mass spectrum with synthetic material.

Of the less successful reactions, *m*-xylene and the 1,3-amino alcohol **3** gave a low yield of a 3:1 mixture

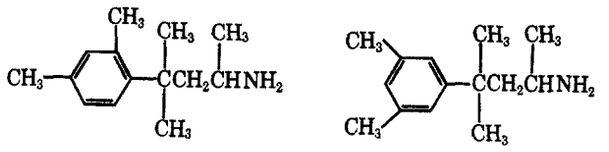
(8) P. D. Caesar, *J. Am. Chem. Soc.*, **70**, 3623 (1948).
(9) R. E. Marker and T. S. Oakwood, *ibid.*, **60**, 2598 (1938).

SCHEME II



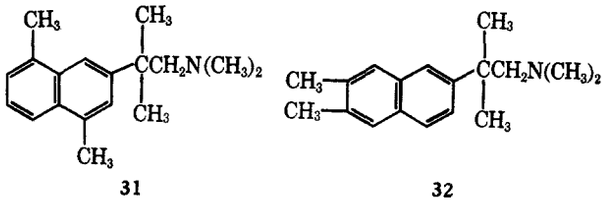
28 29

of the 1,2,4 and 1,3,5 isomers (**30a**, ν_{max} 815, 845, and 875 cm^{-1}; **30b**, ν_{max} 845, 705 cm^{-1}; *cf.* 3,5-dimethyl-*t*-butylbenzene).[10] Anthracene, phenanthrene, and mesitylene gave poor yields and mixtures with **3**.



30a 30b

For further study of the reactions of dimethylamino-2-methyl-2-propanol (**1**) we selected four different dimethylnaphthalenes which on steric grounds seemed likely to yield a single product, assuming that substitution occurred solely in the β position, as with naphthalene. Aluminum chloride catalyzed reactions of **1** with 1,5-dimethylnaphthalene and 2,3-dimethylnaphthalene in *o*-dichlorobenzene gave single products **31** and **32** in 21 and 14% yield, respectively. The structure of **32** is supported by its infrared spectrum, which lacks the bands in the region of 700–800 cm^{-1} characteristic of structures with three and four adjacent aromatic protons. From the reactions of **1** with 1,4-dimethyl-



31 32

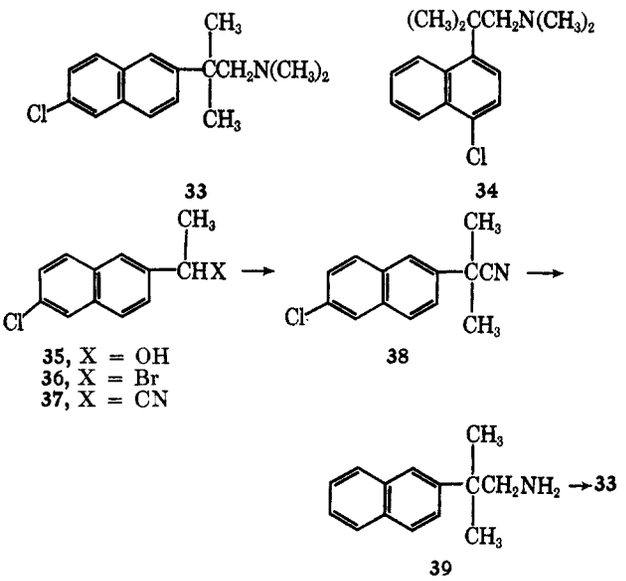
naphthalene in *o*-dichlorobenzene and with neat 1,6-dimethylnaphthalene were obtained mixtures of two or more major and many minor components. Some of the products may result from substitution at sterically less favored positions, but some must result from prior rearrangement of the methyl groups on naphthalene.[11]

The amino alcohol **1** reacted with 2-chloronaphthalene in cyclohexane to give **33**, and with 1-chloronaphthalene to give **34**, although in both cases one might have anticipated heteroannular β substitution. Since succinoylation[12] and acetylation[13] of the mono-

(10) Reference 5, Spectrum No. 5336.
(11) G. Suld and A. P. Stuart [U. S. Patent 3,109,036 (Oct. 29, 1963)] reported that 2,6-dimethylnaphthalene is converted in part to the 1,6 and 1,5 isomers on treatment with boron trifluoride.
(12) E. Berliner, Y. Chu, and N. Shieh, *J. Org. Chem.*, **23**, 633 (1958).
(13) J. L. Jacobs, S. Winstein, J. W. Ralls, and J. H. Robson, *ibid.*, **11**, 27 (1946).

chloronaphthalenes have been shown to give 1,4 and 2,6 substitution, we were provided a simple method for proving the structures of our products. 6′-Chloro-2′-acetonaphthone was converted successively to the alcohol **35**, the bromide **36**, and the nitrile **37**; alkylation of the nitrile carbanion with methyl iodide, reduction with lithium aluminum hydride, and methylation with formaldehyde and formic acid afforded in turn **38**, **39**, and **33** (Scheme III), the latter identical

SCHEME III



with the original Friedel–Crafts product. By the same six steps **34** was synthesized from 4′-chloro-1′-acetonaphthone.

The preparation and properties of the arylalkylamines are given in Tables I and II, respectively.

Experimental Section

Vapor Phase Chromatography (Vpc).—Analyses by vpc utilized the F&M Model 720 fitted with a single 2-ft column of silicone rubber (20%) on Chromosorb W. This column gave complete separation of Friedel–Crafts isomers in most cases where more than one product was formed, *e.g.*, in the reaction with *m*-xylene. This column was also used for preparative separations of samples for mass spectra and combustion analysis.

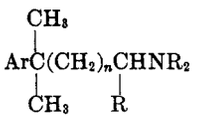
Dimethylamino-2-methyl-2-propanol (1).—Chloro-2-methyl-2 propanol[14] (72 g) and an equal weight of anhydrous dimethylamine were sealed in a bomb tube and heated for 3 days at 90°. The contents of the tube were heated to drive off the excess dimethylamine, then dissolved in water, made strongly basic with solid sodium hydroxide, and extracted with ether. Evaporation and distillation gave 52.4 g (67%), bp 130°.

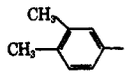
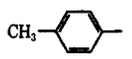
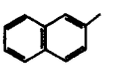
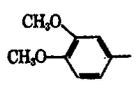
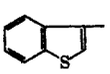
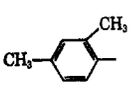
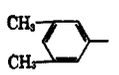
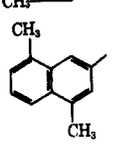
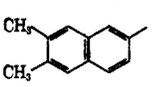
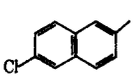
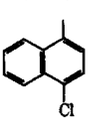
4-Dimethylamino-2-methyl-2-butanol (2).—4-Chloro-2-methyl-2-butanol was prepared according to the method of Campbell and Campbell[8] by addition of 100 g of ethyl 3-chloropropionate to the Grignard solution prepared from 313 g of methyl iodide and 53.5 g of magnesium turnings in ether. The crude chlorohydrin, isolated by decomposition of the Grignard solution with 3 *N* hydrochloric acid and removal and evaporation of the ether layer, was dissolved in 300 ml of acetonitrile. About 200 ml of dry dimethylamine was passed into the ice-cooled solution, which was then heated under reflux for 24 hr. Most of the acetonitrile was removed in a rotary evaporator and the residue was made acidic with 3 *N* hydrochloric acid, then extracted several times with carbon tetrachloride. The extracts were discarded and the aqueous portion was made strongly basic with solid sodium hydroxide. Extraction with ether and evaporation and distillation of the extract gave 28–48 g (30–50%), bp 65–70° (23–24 mm).

4-Amino-2-methyl-2-pentanol (3).—Diacetone alcohol was converted to the oxime in 80–90% yield by treatment with hydroxylamine hydrochloride and potassium carbonate in aqueous solution. The oxime [131 g, bp 95–105° (2 mm)] was dissolved in 100 ml of tetrahydrofuran (THF) and added dropwise with stirring to a solution of 60 g of lithium aluminum hydride in 800 ml of THF. The mixture was heated to reflux for 12–24 hr, then decomposed with 42 ml of water, 60 ml of 15% aqueous sodium hydroxide, and 180 ml of water successively. The resulting mixture was filtered and the filter cake was extracted continuously with ether in a Soxhlet apparatus. The combined extract and filtrate were dried, evaporated, and distilled, yield-

TABLE I

PREPARATION OF



Amine	Ar	R	R′	*n*	Method	Yield, %
7		H	CH_3	0	A	90
8		CH_3	H	1	B	72, 77
9		H	CH_3	2	B	73
10		CH_3	H	3	B	82, 90
40		CH_3	CH_3	1	H	87
41		CH_3	CH_3	3	H	93
11		H	CH_3	0	A	95
12		H	CH_3	0	C	53, 29
13		CH_3	H	1	D	60, 62
14		H	CH_3	2	D	59
15		H	CH_3	3	D	75
42		CH_3	CH_3	1	H	85
16		CH_3	H	1	E	75, 53
17		H	CH_3	2	E	83
18		CH_3	H	3	E	89, 88
43		CH_3	CH_3	1	H	85
44		CH_3	CH_3	3	H	92
19		H	CH_3	1	F	12, 11
20		H	CH_3	2	F	51
21		CH_3	H	3	F	25, 25
25		H	CH_3	1	G	32
26		H	CH_3	2	G	80
27		CH_3	H	3	G	80
45		CH_3	CH_3	3	H	88
30a		CH_3	H	1	B	
30b		CH_3	H	1	B	39
31		H	CH_3	0	I	21
32		H	CH_3	0	I	14
33		H	CH_3	0	C	54
34		H	CH_3	0	A	63

(14) J. Burgin, G. Hearne, and F. Rust, *Ind. Eng. Chem.*, **33**, 385 (1941).

TABLE II
PROPERTIES OF THE ω-ARYLALKYLAMINES AND THEIR HYDROCHLORIDES

Amine	Bp (mm) or mp, °C	Mp of hydrochloride, °C[a]	Hydrochloride recrystallized from	Formula	Calcd, % C	Calcd, % H	Calcd, % N	Found, %[b] C	Found, %[b] H	Found, %[b] N
7	84–88 (1.0)	200 subl	Isopropyl alcohol–THF[c]	$C_{14}H_{24}ClN$	69.54	10.00	5.79	69.43	10.01	5.70
8	105–115 (2.5)	190	THF	$C_{14}H_{24}ClN$	69.54	10.00	5.79	69.43	9.95	5.81
9	105–115 (2.5)	169–170	Acetone	$C_{16}H_{28}ClN$	71.21	10.46	5.19	71.24	10.40	5.31
10*	125–135 (1.5)	143–145	Acteone–THF	$C_{16}H_{27}N$[d]	82.33	11.66	6.00	82.56	11.66	5.99
11	70–80 (0.4)	195–200 subl	Isopropyl alcohol–acetone	$C_{13}H_{22}ClN$	68.54	9.74	6.15	68.46	9.74	6.02
12	125–130 (0.8)	225–235	Isopropyl alcohol–THF	$C_{16}H_{22}ClN$	72.84	8.41	5.31	72.65	8.48	5.27
13	140–145 (1.5)	203–206	Absolute ethanol–ether	$C_{16}H_{22}ClN$	72.84	8.41	5.31	72.52	8.40	5.42
14	150–155 (1.3)	157–159	Acetone–THF	$C_{18}H_{26}ClN$	74.07	8.98	4.80	73.76	9.08	4.73
15*	170–175 (2.0)	181–183	Absolute ethanol–ether	$C_{19}H_{27}N$[d]	84.70	10.10	5.20	84.52	10.03	5.33
16	135–140 (1.5)	175–180	Absolute ethanol–THF	$C_{14}H_{24}ClNO_2$	61.41	8.83	5.12	61.21	8.85	5.10
17	145–150 (2.0)	169–170	Acetone	$C_{16}H_{28}ClNO_2$	63.66	9.35	4.64	63.67	9.40	4.67
18	160–165 (1.5)	122–124	Absolute ethanol–THF	$C_{16}H_{28}ClNO_2$	63.66	9.35	4.64	63.85	9.36	4.67
19	65–70 (0.6)	210–215 subl	Isopropyl alcohol–THF	$C_{11}H_{20}ClNS$	56.50	8.62	5.99	56.48	8.44	5.99
20	65–75 (0.5)	144–147	Acetone	$C_{12}H_{22}ClNS$	58.15	8.94	5.65	57.81	9.01	5.63
21	95–100 (1.0)	123–124	Acetone–ether	$C_{12}H_{22}ClNS$	58.15	8.94	5.65	58.23	8.94	5.54
25*	140–150 (1.3)	Deliquescent	...	$C_{15}H_{21}NS$[d]	72.82	8.56	5.66	72.74	8.72	5.67
26	155–160 (2.0)	205–209	Isopropyl alcohol	$C_{16}H_{24}NSCl$	64.51	8.12	4.70	64.66	8.25	4.63
27*	160–165 (1.5)	225–230	Isopropyl alcohol–methanol	$C_{15}H_{23}NS$[d]	73.51	8.87	5.36	73.11	8.90	5.31
31*	135–145 (0.5)	Dec >230	Isopropyl alcohol–THF	$C_{18}H_{25}N$[d]	84.65	9.87	5.49	85.03	9.92	5.27
32*	130–140 (0.4)	Dec >230	Isopropyl alcohol–THF							
	71–74[e]			$C_{18}H_{25}N$	84.65	9.87	5.49	84.65	9.83	5.14
33	148–153 (1.0)	210–215	Isopropyl alcohol–THF	$C_{16}H_{21}Cl_2N$	64.43	7.10	4.70	64.24	7.19	4.38
	73–76[e]			$C_{16}H_{20}ClN$[d]	73.40	7.70	5.35	73.42	7.74	4.98
34	150 (0.7)	*ca.* 190 subl	Isopropyl alcohol–THF	$C_{16}H_{21}Cl_2N$	64.43	7.10	4.70	64.38	7.25	4.38
40	100–110 (1.5)	205–207	Absolute ethanol–acetone	$C_{16}H_{28}ClN$	71.21	10.46	5.19	71.18	10.43	5.24
41	140–150 (2.0)	144–146	Acetone	$C_{18}H_{32}ClN$	72.57	10.83	4.70	72.49	10.84	4.77
42	140–148 (1.7)	158–160	Absolute ethanol–acetone	$C_{18}H_{26}ClN$	74.07	8.98	4.80	73.96	8.97	4.84
43	140–145 (2.0)	173–175	Absolute ethanol–acetone	$C_{16}H_{28}ClNO_2$	63.66	9.35	4.64	63.61	9.30	4.65
44	155–165 (1.5)	109–111	THF	$C_{18}H_{32}ClNO_2$	65.53	9.78	4.25	65.44	9.82	4.26
45	170–175 (2.7)	170–175	Acetone–THF	$C_{18}H_{28}ClNS$	66.32	8.66	4.30	66.38	8.69	4.16

[a] Decomposition preceded or accompanied melting in most cases. [b] *Cf.* footnote 17. Hydrochlorides of the starred amines gave consistently low carbon analyses. Analytical samples of the free amines were prepared by vapor phase chromatography. [c] Tetrahydrofuran. [d] Formulas and analyses refer to the free amines in these instances. [e] Analytical sample was recrystallized from pentane.

ing 73.6 g (63%) of colorless oil, bp 80–100° (16–18 mm), which largely crystallized.

5-Dimethylamino-2-methyl-2-pentanol (4).—4-Chlorobutyronitrile[15] was converted in 71–74% yield to ethyl 4-chlorobutyrate by the method of Campbell and Campbell.[3] The ester [129 g, bp 80–83° (20 mm)] was added to a Grignard solution prepared from 250 g of methyl iodide and 42.2 g of magnesium turnings in ether.[3] The crude chlorohydrin was isolated and treated with dimethylamine in acetonitrile as described above for amino alcohol **2**, yielding 34.3 g (28%), bp 89–92° (18 mm).

6-Dimethylamino-2-methyl-2-hexanol (5).—6-Bromo-2-methyl-2-hexanol was prepared as described by Campbell and Campbell[3] by addition of methyl 5-bromovalerate[16] (42 g) to the Grignard solution prepared from 63 g of methyl iodide and 10.5 g of magnesium turnings in ether. The crude bromohydrin was isolated and treated with dimethylamine in acetonitrile as described above for amino alcohol **2**, yielding 15.8 g (46%), bp 105–108° (16 mm).

Friedel–Crafts Reactions.—Described below are the best and in most cases the only methods we have found to bring about reaction of an amino alcohol with a particular aromatic substrate. Each product was analyzed by vpc after distillation and found to consist of one material to the extent of 95% or more, except where otherwise noted. Conversion of the product to the hydrochloride and recrystallization of the hydrochloride, followed by regeneration of the free amine, gave in each case a material of 99% or greater purity by vpc except for the Friedel–Crafts products of toluene (**11**) and 2,3-dimethylnaphthalene (**32**), which retained *ca.* 5% of other material. Boiling point ranges are reported for initial products, not regenerated amines. By no method were we able to cause dimethylamino-2-methyl-2-propanol (**1**) to condense with veratrole, thiophene, or benzothiophene.

(15) "Organic Syntheses," Coll. Vol. I, John Wiley and Sons, Inc., A. H. Blatt, Ed., New York, N. Y., 1941, p 156.
(16) Reference 15, Coll Vol III, E. C. Horning, Ed., 1955, p 578.

Method A. 2-(3,4-Dimethylphenyl)-N,N,2-trimethylpropylamine (7), 2-(4-Methylphenyl)-N,N,2-trimethylpropylamine (11), and 4-Chloro-N,N,β,β-tetramethyl-1-naphthaleneethylamine (34).—Dimethylamino-2-methyl-2-propanol (11.7 g) dissolved in 25 ml of hydrocarbon (*o*-xylene or toluene) was added dropwise with stirring to a solution of 33 g of anhydrous aluminum chloride in 150 ml of hydrocarbon. (For **34**, the pure amine was added to a solution of 33 g of aluminum chloride in 100 ml of 1-chloronaphthalene.) The mixture was stirred for 72 hr at 38–40°, then poured onto 300 g of ice and 20 ml of concentrated hydrochloric acid. Hexane was added and the hydrocarbon layer was removed and discarded. The aqueous portion was made strongly basic with solid sodium hydroxide and extracted with ether. The extract was dried over magnesium sulfate, evaporated, and distilled through a short-path column.

Method B. 3-(3,4-Dimethylphenyl)-1,3-dimethylbutylamine (8), 4-(3,4-Dimethylphenyl)-N,N,4-trimethylpentylamine (9), and 5-(3,4-Dimethylphenyl)-1,5-dimethylhexylamine (10).—To 33 g of anhydrous aluminum chloride and 25–30 ml of *o*-xylene in 100 ml of nitrobenzene, chilled in a ice bath, was added dropwise with stirring 0.10 mole of amino alcohol in 25 ml of nitrobenzene. The mixture was stirred for 18 hr at room temperature, then poured onto 300 g of ice and 20 ml of concentrated hydrochloric acid. The mixture was extracted several times with hexane, and the extracts were discarded. The aqueous portion was made strongly basic with solid sodium hydroxide and extracted with ether. The ether extract was dried over magnesium sulfate, evaporated, and distilled through a short-path column. The reaction with *m*-xylene was run on one-fifth the scale above. Samples of the two major products, 3-(2,4-dimethylphenyl)-1,3-dimethylbutylamine (**30a**) and 3-(3,5-dimethylphenyl)-1,3-dimethylbutylamine (**30b**), were collected for infrared and combustion analysis by vpc.

Method C. N,N,β,β-Tetramethyl-2-naphthaleneethylamine (12) and 6-Chloro-N,N,β,β-tetramethyl-2-naphthaleneethylamine (33).—Dimethylamino-2-methyl-2-propanol dissolved in 10 ml of cyclohexane was added dropwise with stirring to a solution of 31 g of anhydrous aluminum chloride and 26 g of naphthalene in 100 ml of cyclohexane, or 43 g of 2-chloronaphthalene in 25 ml of cyclohexane. The mixture was stirred for 18 hr at room temperature, then treated as described above for method B.

Method D. α,γ,γ-Trimethyl-2-naphthalenepropylamine (13), N,N,δ,δ-Tetramethyl-2-naphthalenebutylamine (14), and N,N,ε,ε-Tetramethyl-2-naphthalenepentylamine (15).—To 33 g of anhydrous aluminum chloride and 40 g of naphthalene in 100 ml of nitrobenzene, chilled in an ice bath, was added dropwise with stirring 0.10 mole of amino alcohol in 25 ml of nitrobenzene. The mixture was stirred for 18 hr at room temperature. Work-up was the same as for method B.

Method E. 3-(3,4-Dimethoxyphenyl)-1,3-dimethylbutylamine (16), 4-(3,4-Dimethoxyphenyl)-N,N,4-trimethylpentylamine (17), and 5-(3,4-Dimethoxyphenyl)-1,5-dimethylhexylamine (18).—A solution of 0.10 mole of amino alcohol, 40 ml of veratrole, and 100 ml of nitrobenzene in a 500-ml polyethylene bottle was placed in a Dry Ice–acetone bath, and an equal volume of anhydrous hydrogen fluoride was allowed to condense into the bottle. The solution was then warmed to room temperature and stirred for 6 hr. Most of the remaining hydrogen fluoride was removed under a stream of nitrogen, and the residue was poured onto ice and 20 ml of concentrated hydrochloric acid. Work-up then proceeded as above for method B.

Method F. N,N,3-Trimethyl-3-(2-thienyl)butylamine (19), N,N,4-Trimethyl-4-(2-thienyl)pentylamine (20), and 1,5-Dimethyl-5-(2-thienyl)hexylamine (21).—To 75 ml of anhydrous fuming stannic chloride and 40 ml of thiophene in 150 ml of nitrobenzene was added dropwise with stirring 0.20 mole of amino alcohol in 30 ml of nitrobenzene. After 12–36 hr of stirring at room temperature the mixture was poured onto ice and 25 ml of concentrated hydrochloric acid. (Preparation of **19** required in addition 1 hr of heating on the steam bath.) Work-up proceeded as above for method B.

Method G. N,N,γ,γ-Tetramethyl-3-benzo[*b*]thiophenepropylamine (25), N,N,δ,δ-Tetramethyl-3-benzo[*b*]thiophenebutylamine (26), and α,ε,ε-Trimethyl-3-benzo[*b*]thiophenepentylamine (27).—To 35 ml of anhydrous fuming stannic chloride and 24 g of benzo[*b*]thiophene in 100 ml of nitrobenzene was added dropwise with stirring 0.10 mole of amino alcohol in 30 ml of nitrobenzene. The mixture was stirred for 72–96 hr at 35–40°, then poured onto ice and 20 ml of concentrated hydrochloric acid. Work-up proceeded as described above for method B.

Method H. The Clarke–Eschweiler Reaction. 3-(3,4-Dimethylphenyl)-N,N,1,3-tetramethylbutylamine (40), 5-(3,4-Dimethylphenyl)-N,N,1,5-tetramethylhexylamine (41), N,N,α,γ,γ-Pentamethyl-2-naphthalenepropylamine (42), 3-(3,4-Dimethoxyphenyl)-N,N,1,3-tetramethylbutylamine (43), 5-(3,4-Dimethoxyphenyl)-N,N,1,5-tetramethylhexylamine (44), and N,N,α,ε,ε-Pentamethyl-3-benzo[*b*]thiophenepentylamine (45).—The ω-arylalkylamine (0.65 mole) was dissolved with cooling in 16 g of 90% formic acid, and 16 g of 37% aqueous formaldehyde was added. After initial evolution of carbon dioxide had subsided the mixture was heated at reflux on a steam bath for 5 hr, then poured onto ice, made strongly basic with solid sodium hydroxide, and extracted with ether. The ether extract was dried over magnesium sulfate, evaporated, and distilled through a short-path column.

Method I. N,N,β,β,4,8-Hexamethyl-2-naphthaleneethylamine (31) and N,N,β,β,6,7-Hexamethyl-2-naphthaleneethylamine (32).—To a solution of 30–35 g of 1,5- or 2,3-dimethylnaphthalene in 80–90 ml of *o*-dichlorobenzene was added dropwise with stirring 11.7 g of dimethylamino-2-methyl-2-propanol in 10 ml of *o*-dichlorobenzene. The mixture was stirred for 40 hr at 35–40°, then heated on a steam bath for 1 hr. Work-up was accomplished as described for method B.

2-(1,1-Dimethylpropyl)thiophene (23) by the Friedel–Crafts Reaction.—To 50 g of thiophene and 60 ml of anhydrous fuming stannic chloride in 200 ml of carbon disulfide was added 44 g of *t*-amyl alcohol. The mixture was heated at reflux for 5 hr, then poured onto ice, and extracted with ether. The ether extract was washed with 5% aqueous sodium bicarbonate, dried, evaporated, and distilled, yielding 34 g (39%), bp 195–205°. Analysis by vpc showed one isomer only.

2-(1,1-Dimethylpropyl)thiophene (23) by Degradation of N,N,-3-Trimethyl-3-(2-thienyl)butylamine (19).—To 0.8 g of **19** was added 3 ml of methyl iodide. After a few hours the excess methyl iodide was allowed to boil away, and the methiodide was converted to the hydroxide by treatment in distilled water with freshly prepared silver oxide. The filtered solution of hydroxide was evaporated under reduced pressure and decomposed at about 150° and 5 mm in a small distillation apparatus. The receiver was chilled in a Dry Ice–acetone bath. The product was taken up in ether, dried over magnesium sulfate, and evaporated, leaving 0.4–0.5 g of thiophene derivative **22**. The latter was dissolved in methanol and reduced under 1 atm of hydrogen in the presence of 0.2 g of 10% palladium on charcoal. The filtered methanol solution was diluted with water and extracted with ether. Evaporation of the dried extract left 0.2–0.3 g of colorless oil, shown by vpc to contain a single major component. Infrared and mass spectra are identical with those of **23** from the Friedel–Crafts reaction above.

3,3-Dimethylheptane (24).—The hydrocarbon was synthesized in 5–6% yield according to the method of Marker and Oakwood[9] by addition of 58 g of *t*-amyl chloride and 2 g of cuprous iodide to an ice-cooled Grignard solution prepared by addition of 106 g of *n*-butyl bromide to 18.3 g of magnesium turnings in 150 ml of ether. (*Caution:* The coupling reaction is highly exothermic.) The mixture after standing for 18 hr was decomposed with 3 *N* hydrochloric acid. The ether layer was removed, dried, evaporated, and distilled, the fraction with bp 120–150° being collected. This fraction was shaken successively with concentrated sulfuric acid, water, and 5% aqueous sodium bicarbonate. The hydrocarbon was taken up in pentane, dried, evaporated, and redistilled, yielding 3.5–4 g of colorless oil, bp 135–142°, shown by vpc to be largely a single compound.

3,3-Dimethylheptane (24) by Desulfuration of 2-(1,1-Dimethylpropyl)thiophene (23).—The thiophene derivative **23** (3 g) was heated at reflux for 18 hr in 150 ml of 95% ethanol with *ca.* 60 g of W-2 Raney nickel catalyst. The solution was then filtered and poured into 500 ml of water. The oil that separated was extracted with pentane. The pentane solution was evaporated to about 25 ml, then shaken successively with concentrated sulfuric acid and water. Evaporation of the dried pentane extract left 0.56 g (*ca.* 20%) of an oil which by vpc contained more than 90% of a single component. This was shown by its mass spectrum to be identical with 3,3-dimethylheptane, prepared above.

3-(1,1-Dimethylpropyl)benzo[*b*]thiophene (28) by the Friedel–Crafts Reaction.—To 27 g of benzothiophene and 30 ml of stannic chloride in 100 ml of carbon disulfide was added dropwise 19 g of *t*-amyl alcohol in 20 ml of carbon disulfide. The mixture was heated to gentle reflux for 12 hr, poured onto ice, and extracted

with ether. The extract was washed with dilute aqueous sodium hydroxide, dried, evaporated, and distilled, yielding 28.5 g (70%) of colorless oil, bp *ca.* 120° (2.5 mm). Analysis by vpc showed one isomer only.

Anal.[17] Calcd for $C_{13}H_{16}S$: C, 76.41; H, 7.89. Found: C, 76.55; H, 8.00.

3-(1,1-Dimethyl-3-propylbenzo[*b*]thiophene (28) by Degradation of N,N,γ,γ-Tetramethyl-3-benzo[*b*]thiophenepropylamine (25).—By the same reactions and procedure used above to convert **19** to **23**, 0.8 g of amine **25** was converted to 0.45 g of **28**, which by vpc was *ca* 90% pure. The infrared and mass spectra were identical with those of **28** prepared above by the Friedel–Crafts reaction.

α,β,β-Trimethylbutylbenzene (29).—To an ice-cooled Grignard solution prepared by addition of 87 g of (1-bromoethyl)benzene to 11 g of magnesium turnings in 250 ml of ether was added 40 g of *t*-amyl chloride and 1.5 g of cuprous iodide. The mixture was stirred overnight at room temperature, then decomposed with 3 *N* hydrochloric acid. When the ether layer was dried and evaporated, the residual oil largely crystallized. The solid, probably, α,α′-dimethylbibenzyl, was removed by filtration and washed with a little ether. The filtrate and washings were evaporated and distilled, a 5-g fraction of bp 80–130° (35 mm) being collected. This material was shaken with concentrated sulfuric acid, washed with water, and redistilled, yielding 1.0 g of colorless oil, bp 90–120° (20 mm), containing by vpc a single major component.

Anal. Calcd for $C_{13}H_{20}$: C, 88.56; H, 11.44. Found: C, 88.47; H, 11.52.

α,β,β-Trimethylbutylbenzene (29) by Desulfuration of 3-(1,1-Dimethylpropylbenzo[*b*]thiophene (28).—The benzothiophene derivative **28** (3 g) was heated to reflux for 72 hr with 40–50 g of W-2 Raney nickel catalyst in 100 ml each of 95% ethanol and ether. The mixture was filtered, diluted with 500 ml of water, and extracted with pentane. The evaporated extract was shaken with concentrated sulfuric acid, then with water, and taken up in pentane. Evaporation and distillation yielded 1.25 g, bp *ca.* 120° (30 mm). The major component, which by vpc constitutes about 75% of the product, was shown by its mass spectrum to be identical with α,β,β-trimethylbutylbenzene (**29**) prepared above.

6-Chloro-α-methyl-2-naphthalenemethanol (35).—To 2.5 g of lithium aluminum hydride suspended in 100 ml of THF was added dropwise with stirring 25 g of 6′-chloro-2′-acetonaphthone[13] in 200 ml of THF. The mixture was stirred for 3 hr more, then decomposed with 6 ml of water, and filtered. The filter cake was extracted with hot acetone, and the organic material was combined and evaporated to give 24.3 g of solid, mp 102–103° after recrystallization from ether (lit.[18] mp 101.8–102.2°).

2-(1-Bromoethyl)-6-chloronaphthalene (36).—To 23.3 g of alcohol **35**, largely dissolved in 200 ml of carbon tetrachloride, was added dropwise with stirring 12 g of phosphorus tribromide in 40 ml of carbon tetrachloride. Addition took 2 hr, after which the solution was allowed to stand for 18 hr at room temperature. The solution was then washed several times with ice–water, dried, and evaporated. The residual solid was recrystallized from ether, yielding 27.5 g (90%) with mp 85–91°, 87–89° after repeated recrystallization from ether.

Anal. Calcd for $C_{12}H_{10}BrCl$: C, 53.46; H, 3.74. Found: C, 53.42; H, 3.80.

6-Chloro-α-methyl-2-naphthaleneacetonitrile (37).—To a solution of 6 g of sodium cyanide in 100 ml of dimethyl sulfoxide was added with cooling 27 g of bromide **36** in 100 ml of dimethyl sulfoxide. The solution was allowed to stand for 48 hr at room temperature; then it was poured into 3 l. of water and extracted with ether. The ether extract was washed repeatedly with water, dried, and evaporated, giving 11.5 g (53%) of crystalline solid with mp 72–73° after recrystallization from ether.

Anal. Calcd for $C_{13}H_{10}ClN$: C, 72.39; H, 4.67; N, 6.50. Found: C, 72.09; H, 4.80; N, 6.16.

6-Chloro-α,α-dimethyl-2-naphthaleneacetonitrile (38).—To 8.9 g of nitrile **37** in 100 ml of ether under nitrogen was added with stirring 1.8 g of sodium amide. The mixture was heated at reflux for 20 min; then 6.5 g of methyl iodide was added dropwise. After an additional 90 min at reflux the mixture was poured onto ice and shaken with ether. The ether solution was decolorized with charcoal and evaporated, yielding 7 g (74%) of brown solid, mp 85–89° after several recrystallizations from ether.

(17) Scandinavian Microanalytical Laboratory, Herlev, Denmark.

(18) C. C. Price and G. H. Shilling, *J. Am. Chem. Soc.*, **70**, 4265 (1948).

Anal. Calcd for $C_{14}H_{12}ClN$: C, 73.20; H, 5.27; N, 6.10. Found: C, 73.13; H, 5.33; N, 5.95.

6-Chloro-β,β-dimethyl-2-naphthaleneethylamine (39).—To 6.6 g of crude nitrile **38** in 70 ml of THF was added in portions 1.1 g of lithium aluminum hydride. After 17 hr at slow reflux the mixture was decomposed with 2.5 ml of water and filtered. The filter cake was extracted in a Soxhlet extractor with ether, and the combined organic material was treated with 20 ml of 3 *N* hydrochloric acid. The aqueous portion was separated and made basic with solid sodium hydroxide, resulting in separation of an oil which crystallized on cooling. The solid (3.9 g, 58%) was decolorized with charcoal and recrystallized from pentane: mp 88–90°.

Anal. Calcd for $C_{14}H_{16}ClN$: C, 71.93; H, 6.90; N, 5.99. Found: C, 71.92; H, 6.91; N, 5.70.

The Clarke–Eschweiler product of this amine, decolorized with charcoal and recrystallized from pentane, had mp 72–75° and was shown by its infrared spectrum to be identical with the Friedel–Crafts product (**33**) of dimethylamino-2-methyl-2-propanol and 2-chloronaphthalene.

1-(1-Bromoethyl)-4-chloronaphthalene.—4-Chloro-α-methyl-1-naphthalenemethanol (bp 135–140° at 0.5 mm) was prepared in 93% yield by lithium aluminum hydride reduction of 4′-chloro-1′-acetonaphthone[13] as described for **35**, and was converted to the bromide by treatment with phosphorus tribromide as described for **36**. The bromide did not crystallize and attempts to distil it resulted in dehydrobromination, but most of the solvent could be removed under vacuum at 80–100° without decomposition of the bromide.

4-Chloro-α-methyl-1-naphthaleneacetonitrile.—Crude 1-(1-bromoethyl)-4-chloronaphthalene from 95.6 g of the alcohol was added with cooling to 500 ml of dimethyl sulfoxide in which was dissolved 25 g of sodium cyanide. Treatment as described above for **37** gave 75 g (75%) of viscous oil, bp 150–160° (0.8 mm).

Anal. Calcd for $C_{13}H_{10}ClN$: C, 72.39; H, 4.67; N, 6.50. Found: C, 72.52; H, 4.72; N, 6.07.

4-Chloro-α,α-dimethyl-1-naphthaleneacetonitrile.—To a solution of 75 g of 4-chloro-α-methyl-1-naphthaleneacetonitrile in 500 ml of ether under nitrogen was added 18 g of sodium amide. After 6 hr at reflux on a steam bath the mixture was cooled slightly and a solution of 60 g of methyl iodide in ether was added at such a rate that slow reflux was maintained. Heating was continued for 2 hr after addition was complete, and the reaction was worked up as described for **38**, yielding 60.3 g of oil, bp 148–150° (0.4 mm), that largely solidified. Alkylation was about two-thirds complete as shown by vpc of the crude product. Recrystallization from ether and pentane gave a white solid, mp 102–104°.

Anal. Calcd for $C_{14}H_{12}ClN$: C, 73.20; H, 5.27; N, 6.10. Found: C, 73.29; H, 5.38; N, 5.90.

4-Chloro-β,β-dimethyl-1-naphthaleneethylamine.—To 4 g of lithium aluminum hydride in 300 ml of THF was added dropwise with stirring 19.5 g of the nitrile above in 150 ml of THF. The mixture was heated at reflux for 24 hr, then decomposed with 10 ml of water, and filtered. The filter cake was extracted with ether in a Soxhlet apparatus, and the combined organic material was evaporated to *ca.* 100 ml and poured into 125 ml of 3 *N* hydrochloric acid. The hydrochloride (8.8 g, 40%) crystallized from solution, and 3.3 g (16%) of the free amine was obtained by making the aqueous portion basic and extracting with ether. The hydrochloride had mp 270–280° dec after recrystallization from methanol–THF.

Anal. Calcd for $C_{14}H_{17}Cl_2N$: C, 62.23; H, 6.34; N, 5.19. Found: C, 61.80; H, 6.41; N, 4.77.

The Clarke–Eschweiler product of this amine was shown by its infrared spectrum and by vpc to be identical with the Friedel–Crafts product **34** of 1-chloronaphthalene and dimethylamino-2-methyl-2-propanol.

4-Chloro-β-methyl-1-naphthaleneethylamine.—By treating 4-chloro-α-methyl-1-naphthaleneacetonitrile (74 g) with lithium aluminum hydride (13 g) as described above for the preparation of 4-chloro-β,β-dimethyl-1-naphthaleneethylamine, there was obtained 23 g (26%) of hydrochloride and 10.5 g (13%) of free amine, bp 130–140° (0.6 mm). The hydrochloride, mp 285–290° dec after recrystallization from methanol–THF, did not give a satisfactory combustion analysis. An analytical sample of the free amine was prepared by vpc.

Anal. Calcd for $C_{13}H_{14}ClN$: C, 71.06; H, 6.42; N, 6.38. Found: C, 71.16; H, 6.38; N, 5.96.