only a short distilling head yielded fractions as follows: (A) 30.2 g., b.p. up to 166° (0.25 mm.), $n^{25}\text{D}$ 1.4660; (B) 122.1 g. (46%) of I, b.p. 164–165° (0.1 mm.), $n^{25}\text{D}$ 1.5140–1.5189; (C) 28.6 g. of material in the Dry Ice trap which protected the pump.

Fraction B, upon redistillation from 5 g. of anhydrous potassium carbonate through a 20-cm. modified Claisen head, yielded 89.6 g. (34%) of clear, colorless I, b.p. 167–170° (0.06 mm.), $n^{25}\text{D}$ 1.5182–1.5187, $n^{25}\text{D}$ 1.5183, d^{25}_{4} 1.2284; M_D calcd.[6] 65.25, found 64.85. The saponification equivalent[7] of I ($n^{29}\text{D}$) was 137 (calcd. for saponification and dehydrohalogenation of I, 131).

Anal. Calcd. for $C_{11}H_{15}ClO_3S$: C, 50.28; H, 5.76; Cl, 13.49; S, 12.20. Found: C, 50.25; H, 5.80; Cl, 13.89; S, 12.26.

When I was distilled without potassium carbonate, small amounts of flocculent white solid appeared in the distillate. Solid of similar properties also resulted upon heating I alone at 215° for 45 minutes, and was identified as *p*-toluenesulfonic acid; S-benzylthiuronium salt, m.p. 182–183°, reported[8] m.p. 181–182°. Distillation from carbonate helps prevent this decomposition, apparently autocatalytic.

(b) **By-products.**—Redistillation of fraction A through an 18-cm. modified Claisen head yielded 1.4 g. (fraction D, presumably III), b.p. up to 42° (8 mm.), $n^{25}\text{D}$ 1.4526, together with 18.1 g. (18%, based on *p*-toluenesulfonyl chloride) of 4,4′-dichlorodibutyl ether (II), b.p. 122.5–123° (8.0 mm.), $n^{25}\text{D}$ 1.4565–1.4585. Further distillation of a portion of the II gave material having b.p. 116° (6 mm.), $n^{25}\text{D}$ 1.4565; reported[4] for II, 84–86° (0.5 mm.), $n^{25}\text{D}$ 1.4567.

Anal. Calcd. for $C_8H_{16}Cl_2O$: C, 48.25; H, 8.10; mol. wt., 199. Found: C, 48.51; H, 8.39; mol. wt. (Rast), 190.

Fraction C, dried and redistilled through a semi-micro column,[9] gave 6.5 g. of 1,4-dichlorobutane (III), b.p. 43.5° (10 mm.), 154–156°, $n^{25}\text{D}$ 1.4517; reported[10] b.p. 155°, $n^{20}\text{D}$ 1.4542. The total yield of III, including fraction D, was 7.9 g. (12%, based on *p*-toluenesulfonyl chloride).

Anal. Calcd. for $C_4H_8Cl_2$: C, 37.82; H, 6.35. Found: C, 38.04; H, 6.53.

(c) **Variations in Reaction Conditions.**—Portionwise addition of the zinc chloride, or reduction of its amount to one-half, had no significant effect. The use of iodine as a catalyst gave I in 32% crude yield, but cadmium chloride gave I in only about 3% yield, and anhydrous aluminum chloride or boron trifluoride etherate gave even less.

Doubling the scale of (a) or reduction to one-fifth scale was without apparent effect. On a doubled scale, however, two condensers are desirable, owing to the large volume of refluxing tetrahydrofuran during the exothermic phase; the larger amount of product was best distilled in two or more portions, to minimize exposure to heat and the decomposition referred to above.

Moderate variations in the time of heating (after the exothermic phase of the reaction) seemed to have little effect. Thus a 10-hour period at 125–130° gave I in 35% yield, $n^{29}\text{D}$ 1.5160, and a period of 4.5 hours at 95–100° reduced the yield only slightly (28%, $n^{25}\text{D}$ 1.5185–1.5193); a heating period of only 0.3 hour (including the exothermic phase), however, resulted in negligible I. Cooling during the exothermic phase of the reaction, so that the temperature was maintained at 90–100°, proved to be undesirable; compound I was then isolated in only 10% yield ($n^{25}\text{D}$ 1.5168–1.5182).

Larger excesses of tetrahydrofuran, or protection of the reaction from moisture by calcium chloride tubes and a sealed stirrer, conferred no advantages.

Reaction of I with Inorganic Halides. (a) **Sodium Iodide.**—For the preparation of 1-chloro-4-iodobutane, I (12.5 g.) and 22 ml. of acetone were added to 7.2 g. of anhydrous sodium iodide in 50 ml. of acetone. Precipitation began within a few seconds, and after 48 hours resulted in 91% of the expected sodium *p*-toluenesulfonate. The solid was collected, the acetone was removed using a 25-cm. Vigreux column, and the residue was distilled using a 7-cm. modified Claisen flask. After redistillation through a semi-micro column,[9] the yield of 1-chloro-4-iodobutane was 6.3 g. (60%), b.p. 90–93° (17 mm.), $n^{25}\text{D}$ 1.5382–1.5387. A portion having $n^{25}\text{D}$ 1.5385 was analyzed[11]; d^{25}_{4} 1.7853; M_D calcd. 38.34, found 38.31.

Anal. Calcd. for C_4H_8ClI: C, 21.99; H, 3.69; Cl, 16.23; I, 58.09. Found: C, 21.98; H, 3.70; Cl, 16.13; I, 57.71.

(b) **Lithium Chloride.**—In order to determine the feasibility of destroying I with anhydrous lithium chloride, 2.02 g. was heated with 10.5 g. of I in 50 ml. of acetone, with stirring at the reflux temperature for 48 hours. The mixture was then concentrated to 30 ml. and poured into water. Ether extracts were dried, the ether removed, and the residue distilled; yield of 1,4-dichlorobutane (III), 2.74 g. (54%), b.p. 154°, $n^{20}\text{D}$ 1.4514–1.4542. The tarry residue from the distillation amounted to only 0.21 g. (2% recovery, if assumed to be I).

Reaction of I with Phenylmagnesium Bromide.—Compound I (88.6 g., 0.34 mole) was added during 2 hours, together with ether as necessary to permit efficient stirring, to 75 ml. of 2.25 *N* phenylmagnesium bromide. The mixture was stirred and heated under moderate reflux for 16 hours, and was then hydrolyzed with cold dilute hydrochloric acid. Ether extracts were washed with saturated sodium bicarbonate solution and water until neutral, and were dried over anhydrous sodium sulfate. Two fractionations, the last through a 15-cm. helix-packed column, gave 15.2 g. (52%) of 1-bromo-4-chlorobutane (IV), b.p. 58–58.5° (10 mm.), $n^{25}\text{D}$ 1.4835–1.4843 (reported[12] b.p. 63–64° (10 mm.), $n^{20}\text{D}$ 1.4865); IV ($n^{25}\text{D}$ 1.4843) contained 29.56% C and 5.04% H (calcd. for IV: C, 28.01; H, 4.70). Some improvement in the purity of the IV was effected by washing with concentrated sulfuric acid, drying and refractionation (C, 28.70; H, 4.90).

Two fractionations, the last through a 15-cm. column, also were used to separate the 4-chlorobutylbenzene (V), which then amounted to 7.61 g. (27%), b.p. 108.5–111.5° (13 mm.), $n^{25}\text{D}$ 1.5177–1.5195; reported[2b] b.p. 98–102° (6 mm.), $n^{25}\text{D}$ 1.5183. V of $n^{25}\text{D}$ 1.5185 contained 71.85% C and 7.82% H (calcd. for V: C, 71.21; H, 7.77). Washing the V with concentrated sulfuric acid and refractionating it resulted in no improvement in its analysis.

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(6) The M_D used for the –SO₂O– group was 10.99, as given by R. H. Wiley and R. P. Davis for –SO₂O– in *n*-butyl *p*-toluenesulfonate (THIS JOURNAL, **74**, 6142 (1952).

(7) Heating was effected at 150° for 5 minutes. Otherwise the procedure was that involving diethylene glycol, R. L. Shriner and R. C. Fuson, "The Systematic Identification of Organic Compounds," 2nd ed., John Wiley and Sons, Inc., New York, N. Y., 1940, p. 118.

(8) E. Chambers and G. W. Watt, *J. Org. Chem.*, **6**, 376 (1941).

(9) C. W. Gould, Jr., G. Holzman and C. Niemann, *Anal. Chem.*, **20**, 361 (1948).

(10) M. S. Kharasch and G. Buchi, THIS JOURNAL, **73**, 632 (1951).

(11) 1-Chloro-4-iodobutane was obtained by K. Ahmad and F. M. Strong, but in an estimated purity of only 94%, b.p. 93–94.5° (17 mm.); THIS JOURNAL, **70**, 1699 (1948).

(12) Y. K. Yur'ev, K. M. Minachev and K. A. Samurskaya, *J. Gen. Chem.*, (*U.S.S.R.*), **9**, 1710 (1939) [*C. A.*, **34**, 3731 (1940)].

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The Piperidine-catalyzed Reaction of Triphenylsilane with Some Hydroxy Compounds

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In some studies on the kinetics of hydrolysis of triarylsilanes in methyl cellosolve containing water and piperidine it was found that at low water concentrations the reaction became principally one of alcoholysis. Therefore it appeared that this method might be generally applicable to the preparation of alkoxysilanes.

$$Ar_3SiH + HOCH_2CH_2OCH_3 \xrightarrow{C_5H_{10}NH} Ar_3SiOCH_2CH_2OCH_3 + H_2$$

Table I shows that the reaction has been used successfully for the preparation of five triphenylalkoxysilanes, one triphenylaryloxysilane and two hexaaryldisiloxanes. At-

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[1] E. I. du Pont de Nemours and Co. Fellow, Iowa State College, 1950–1951.

tempts to effect the reaction of triphenylsilane with allyl alcohol, *t*-butyl alcohol, triphenylcarbinol, tetrahydrofurfuryl alcohol, benzhydrol and tri-1-naphthylsilanol were unsuccessful. Hexaphenyldisiloxane was an important by-product in most of these reactions whether the desired product was obtained or not.

TABLE I

REACTIONS OF TRIPHENYLSILANE WITH COMPOUNDS OF THE TYPE ROH

			$(C_6H_5)_3SiOR$		
ROH	Reflux, hr.	Yield, %	M.p., °C.[a]	Silicon, %[b] Calcd.	Found
C_2H_5OH	4.5	40	65–66	..	..[c]
HOC_2H_4OH	4	54	111–112.5	8.76	8.74, 8.83[d]
$CH_3OC_2H_4OH$	1	78	67–68	8.39	8.43, 8.47
s-C_4H_9OH	8	38	120–122	8.43	8.47, 8.52
$C_6H_5CH_2OH$	2.5	73	84–85.5[e]	7.66	7.81, 7.82
o-$CH_3C_6H_4OH$	3.5	82	72–74[e]	7.66	7.84, 7.93
$(C_6H_5)_3SiOH$[f]	4	45	220–221	..	..[c]
(*p*-$CH_3C_6H_4)_3$-SiOH[f]	72	35	160–162	..	..[c]

[a] Uncorrected. [b] Silicon analyses by the method of H. Gilman, B. Hofferth, H. W. Melvin and G. E. Dunn, THIS JOURNAL, **72**, 5767 (1950). [c] Identified by mixed melting point with a known sample. [d] Mol. wt. (cryoscopic in benzene) calcd. for $C_{20}H_{20}O_2Si$, 320.4; found, 320, 323. [e] A mixed m.p. between triphenylbenzyloxysilane and triphenyl-*o*-cresyloxysilane was depressed about 20°, showing that the triphenylbenzyloxysilane preparation is not complicated by rearrangements of the benzyl group as is the case in certain Grignard reactions. [f] Dissolved in dry xylene. See introduction to the Experimental part.

Previous methods for the preparation of triarylalkoxysilanes and triarylaryloxysilanes have been reviewed recently,[2] as have methods for the preparation of unsymmetrical disiloxanes.[3] The most convenient and versatile of the previous methods for the synthesis of either of these types of compounds has been the reaction between a triarylchlorosilane and a metal salt of an alcohol, phenol or silanol. Of the compounds listed in Table I only triphenylethoxysilane,[2,4] hexaphenyldisiloxane[3,5] and 1,1,1-triphenyl-3,3,3-tri-*p*-tolyldisiloxane[3] have been prepared previously.

Our data is not extensive enough to permit any broad generalizations as to the relative merits of the older methods and our preparation from triarylsilanes. It appears that the method using triarylchlorosilanes gives better yields and is successful in one case, at least, where the triarylsilane method failed. It should be mentioned, however, that optimum conditions for the triarylsilane method have not been worked out and particular care has not been taken to work under anhydrous conditions, so that the yields from this method may well be capable of improvement. The method using triarylsilanes, where applicable, has two advantages. First, the triphenylsilane is less subject to hydrolysis during manipulation than is triphenylchlorosilane. Second, all reagents and products except triphenylsilane and the oxysilane are frequently volatile liquids or gases. Thus, upon completion of the reaction, the liquids can be distilled and the product obtained as a residue without the necessity of separating it from an inorganic by-product.

Experimental

The triphenylsilane used in this investigation was prepared by the reduction of triphenylchlorosilane with lithium aluminum hydride.[6] All the compounds of Table I were synthesized by one procedure which is illustrated by the preparation of triphenyl-2-methoxyethoxysilane described below. The only important modification of this procedure was for the solid alcohols and silanols. The weight of these solid reagents theoretically necessary to react with 0.020 mole of triphenylsilane was dissolved in 75 ml. of xylene, and this solution was used in place of a liquid alcohol in the procedure below.

Triphenyl-2-methoxyethoxysilane.—A 125-ml. round-bottomed flask was equipped with a reflux condenser to the outlet of which a gas-washing bottle containing Nujol was attached through a calcium chloride tube. In the flask were placed 5.2 g. (0.020 mole) of triphenylsilane, 75 ml. (0.95 mole) of methyl cellosolve and 10 ml. (0.10 mole) of piperidine. Gas evolution began as soon as the piperidine was added, and it continued for half an hour while the solution was refluxed. When gas ceased to escape through the Nujol, the refluxing was continued for another half-hour, then the solvent was distilled under the vacuum from a water aspirator. On standing overnight the residual oil crystallized to a solid melting at 60–65°. This was taken up in a slight excess of hot petroleum ether (b.p. 60–70°). On cooling, the solution deposited 0.5 g. (9.4%) of hexaphenyldisiloxane, m.p. 210–211°. The petroleum ether solution was filtered, concentrated to about half-volume, and allowed to cool in a refrigerator. The crystalline material, 4.2 g., which separated was removed and the mother liquor again concentrated to half-volume. A second crop of 1.0 g. brought the total yield of triphenyl-2-methoxyethoxysilane to 5.2 g. (78%). Its melting point was 67–68°.

Attempted Preparations.—When triphenylsilane was treated with allyl alcohol in the manner described above, the only product isolated was hexaphenyldisiloxane in 62% yield. Similarly, only hexaphenyldisiloxane was obtained in attempted reactions with tetrahydrofurfuryl alcohol[7] and *t*-butyl alcohol. Attempted reaction of triphenylsilane with triphenylcarbinol, tri-1-naphthylsilanol and benzhydrol led to the formation of some hexaphenyldisiloxane and the recovery of 75–95% of the alcohol or silanol. Triphenylbenzhydryloxysilane has been prepared in 27% yield from triphenylchlorosilane and the sodium salt of benzhydrol.[8]

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[2] H. Gilman and G. N. R. Smart, *J. Org. Chem.*, **19**, 441 (1954).

[3] H. Gilman, H. N. Benedict and H. Hartzfeld, *ibid.*, **19**, 419 (1954).

[4] A. Polis, *Ber.*, **19**, 1012 (1886); H. Gilman and L. S. Miller, THIS JOURNAL, **73**, 968 (1951).

[5] F. S. Kipping and L. L. Lloyd, *J. Chem. Soc.*, **79**, 449 (1901); W. Dilthey and F. Eduardoff, *Ber.*, **37**, 1139 (1904); W. C. Schumb and C. M. Saffer, THIS JOURNAL, **61**, 363 (1939); **63**, 93 (1941); H. H. Szmant and G. A. Brost, *ibid.*, **72**, 5763 (1950); H. W. Melvin, Jr., Doctoral Dissertation, Iowa State College, 1953.

[6] H. Gilman and G. E. Dunn, THIS JOURNAL, **73**, 3404 (1951).

[7] Unpublished studies by J. J. Goodman.

[8] Unpublished studies by T. C. Wu.

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Studies on Bis-(benzylisoquinolines). I. Synthesis of *dl*-N-(4-Hydroxyphenylacetyl)-5-iodo-4-acetoxy-3-methoxyphenylalanine Methyl Ester

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The alkaloid isochondrodendrine (I) is a bis-(benzylisoquinoline) of the curare group, and methods of synthesizing it are of medical as well as chemical interest.[1,2] An Ullmann diphenyl ether condensa-

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[1] A. Burger, "Medicinal Chemistry," Vol. I, Interscience Publishers, Inc., New York, N. Y., 1951. p. 390.

[2] R. H. F. Manske and H. L. Holmes, "The Alkaloids," Vol. IV, Academic Press, Inc., New York, N. Y., 1954, p. 199.