

vessel.⁷ After 1 hr 25 ml of ammonia was distilled into the mixture; this was then followed by the addition of 105 mg of lithium wire (15 mg atoms, six pieces). After 15 min the dark-blue color was discharged by the rather cautious addition (*ca.* 5 min) of ammonium chloride¹¹ (*ca.* 1.5 g) and the ammonia was allowed to evaporate. After the residue had been partitioned between aqueous NaCl and Et₂O, the organic layer was dried, concentrated, and analyzed by glpc. After chromatography (alumina, petroleum ether) a colorless liquid (0.86 g, 95%) was isolated which was identical with an authentic sample of 1,1-diphenylethane.¹²

1-Phenylindan.—Into a metal-ammonia reaction vessel⁷ containing 210 mg of lithium wire (30 mg-atoms, 12 pieces which had been hammered to a foil) in 10 ml of ether was slowly added a solution of 1.18 g (7.5 mmol) of bromobenzene in 7 ml of ether. After 1 hr a solution of 658 mg (5 mmol) of 1-indanone in 8 ml of ether was slowly added and the mixture was stirred for an additional 1 hr. Ammonia (*ca.* 25 ml) was distilled into the mixture and, once the dark-blue color of the mixture was established, *ca.* 1.6 g of ammonium chloride was cautiously added¹¹ (*ca.* 4 min) to discharge the blue color and the ammonia was allowed to evaporate. After the residue had been partitioned between aqueous NaCl and ether, the organic phase was dried, concentrated, and analyzed (glpc). Following chromatography (alumina, petroleum ether) white crystalline material (935 mg,

(11) The ammonium chloride was most conveniently introduced by attaching a glass tube filled with the salt to a side arm with tygon tubing. When the ammonium chloride is to be added the tube is raised and tapped gently to smoothly introduce the quenching agent. Should this step start to become violent, the addition and the vigorous stirring should be momentarily stopped to avoid an eruption.

(12) J. S. Reichert and J. A. Nieuwland, *J. Amer. Chem. Soc.*, **45**, 3090 (1923).

97%) was isolated and compared with an authentic sample prepared by a classical procedure.¹³

Triphenylmethane.—To a solution of 7.2 mmol of phenyllithium (4.5 ml of a 19.7% ether-benzene solution) in 10 ml of ether in a metal-ammonia reaction vessel⁷ was added, dropwise and with stirring, 908 mg (5 mmol) of benzophenone in 10 ml of ether. After 1 hr *ca.* 25 ml of ammonia was distilled into the mixture and then 210 mg of lithium wire (30 mg-atoms, 12 pieces) was quickly added. After 15 min *ca.* 2.9 g of ammonium chloride was cautiously added¹¹ (*ca.* 4 min) to discharge the dark-blue color and the ammonia was allowed to evaporate. The residue was partitioned between ether and aqueous NaCl, and the ethereal layer was dried, concentrated, and analyzed (glpc). Chromatography (alumina, petroleum ether) yielded 1.22 g (97%) of a white crystalline compound which was identical with a commercial sample of triphenylmethane.

Registry No.—MeLi, 917-54-4; BuLi, 109-72-8; PhLi, 591-51-5.

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(13) This is a good example of what we called a classic procedure (alkylation-dehydration-catalytic reduction) earlier in the discussion. The alcohol 1-phenylindanol, prepared by the phenylation of 1-indanone using a Grignard reagent, was dehydrated by distillation from KHSO₄, and the resulting olefin 1-phenylindene was hydrogenated over Raney nickel. See Pl. A. Plattner, R. Sandrin, and J. Wyss, *Helv. Chim. Acta*, **29**, 1604 (1946).

Alkylation-Reduction of Carbonyl Systems. III. The Selective Synthesis of Aromatic Hydrocarbons and Alcohols by the Alkylation-Reduction of Benzylidene Carbonyl Compounds

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Lithium-ammonia reduction of benzylidene benzyl alkoxides, generated *in situ* by alkylation of benzylidene ketones and aldehydes, yields aromatic hydrocarbons when quenched with ammonium chloride and alcohols when quenched with sodium benzoate. The following examples are cited. Phenylation-reduction of benzylidene acetophenone yields 1,1,3-triphenylpropane and 1,1,3-triphenylpropanol, respectively; benzylidene acetone yields 1,3-diphenylbutane and 1,3-diphenyl-3-butanol, respectively; benzylidene propanal yields 1,3-diphenyl-2-methylpropane and 1,3-diphenyl-2-methylpropanol, respectively; benzylidene acetaldehyde yields 1,3-diphenylpropane and 1,3-diphenylpropanol, respectively. Methylation-reduction of benzylidene acetophenone yields 1,3-diphenylbutane and 1,3-diphenyl-3-butanol, respectively; and benzylidene acetone yields 1-phenyl-3-methyl-3-butanol with either quenching agent since the intermediate alkoxide is not benzylic. Mechanistic implications are discussed.

Recently we introduced the concept of tandem alkylation-reduction of aromatic carbonyl systems as a convenient method of preparing aromatic hydrocarbons by the lithium-ammonia reduction of benzyl alkoxides generated *in situ* by alkylation.¹ In addition this laboratory has demonstrated the mechanistic and selective synthetic utility of using ammonium chloride *vis-à-vis* sodium benzoate as quenching agents in metal-ammonia reductions.² We now wish to report our first example of the combination of these two procedures for the selective synthesis of aromatic

hydrocarbons and alcohols by the alkylation-reduction of benzylidene ketones and aldehydes. It is a method which is characterized by its simplicity, selectivity, and excellent isolated yield of the desired product. In addition the mechanistic implications are obvious.

The general procedure is to generate a benzylidene benzyl alkoxide in a metal-ammonia reaction vessel³ by the addition of the benzylidene ketone or aldehyde to the organolithium reagent in ether. Ammonia is subsequently distilled into the vessel, followed by the addition of lithium wire; and then the resulting dark-blue mixture is cautiously quenched.

The sequence is outlined in Scheme I using two examples. Alkylation of benzylideneacetophenone (1)

(1) (a) Part I: S. S. Hall and S. D. Lipsky, *J. Chem. Soc., Chem. Commun.*, 1242 (1971). (b) Part II: S. S. Hall and S. D. Lipsky, *J. Org. Chem.*, **38**, 1735 (1973). (c) S. S. Hall and S. D. Lipsky, submitted for publication in "Organic Syntheses."

(2) (a) S. S. Hall, S. D. Lipsky, and G. H. Small, *Tetrahedron Lett.*, 1853 (1971); (b) S. S. Hall, S. D. Lipsky, F. J. McEnroe, and A. P. Bartels, *J. Org. Chem.*, **36**, 2588 (1971).

(3) For a useful general discussion of metal-ammonia experimental techniques see R. L. Augustine, Ed., "Reduction," Marcel Dekker, New York, N. Y., 1968, pp 98-105.

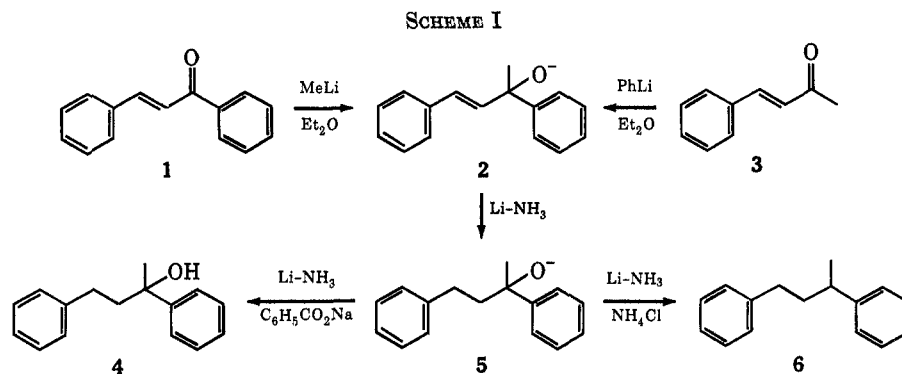


TABLE I
ALKYLATION-REDUCTION OF BENZYLIDENE CARBONYL COMPOUNDS^a

Carbonyl compound	Registry no.	Organo-lithium reagent	Product		Product			
			Quenching agent NH ₄ Cl	Registry no.	% yield anal. ^b /isol. ^c	Quenching agent C ₆ H ₅ CO ₂ Na	Registry no.	% yield anal. ^d /isol. ^e
	94-41-7	C ₆ H ₅ Li		19120-39-9	100/96		6880-25-7	100/87
	122-57-6	C ₆ H ₅ Li		1520-44-1	97/84		19332-07-1	100/97
	109-39-3	C ₆ H ₅ Li		1520-46-3	99/98		38857-84-0	99/96
	104-55-2	C ₆ H ₅ Li		1081-75-0	91/77		14097-24-6	99/91
		CH ₃ Li		1520-44-1	99/89		6880-25-7	100/98
		CH ₃ Li		103-05-9	98/96			100/98

^a Reaction conditions are those discussed in the Experimental Section. ^b Analyzed by glpc using a 6 ft × 0.25 in. 10% Apiezon L on 60-80 Chromosorb W (AW, DMCS) stainless steel column on a flame-detector instrument at a 40-ml/min flow rate. ^c Column chromatography on neutral aluminum oxide (activity I) and eluted with petroleum ether. ^d Analyzed by glpc using a 4 ft × 6 mm 4% silicone gum rubber UCC-W-982 (methylvinyl) on 80-100 HP Chromosorb W (AW, DMCS) all-glass column on a flame-detector instrument at a 40-ml/min flow rate. ^e Column chromatography on neutral aluminum oxide (activity III) and eluted with petroleum ether, petroleum ether-Et₂O.

with methyllithium or benzylideneacetone (3) with phenyllithium generates the benzylidene benzyl alkoxide 2, which in the presence of lithium-ammonia is evidently reduced to the benzyl alkoxide 5, since quenching the reaction mixture with sodium benzoate yields 1,3-diphenyl-3-butanol (4) quantitatively.⁴ In contrast, the use of ammonium chloride as the quenching agent yields 1,3-diphenylbutane (6).

These results imply that at the time of quench the benzyl alkoxide 5 is present in the reaction mixture, since it has been demonstrated that benzyl alkoxides yield similar results when subjected to these conditions.^{1,2} The use of sodium benzoate, a procedure introduced by this group which destroys the excess reducing agent in the absence of an external proton source, protects a benzyl alkoxide intermediate,

(4) This can be viewed as the metal-ammonia reduction of a styrene which is known to reduce to the aromatic hydrocarbon in the absence of an added proton source. See (a) ref 3, pp 118-119; (b) H. Smith, "Organic Reactions in Liquid Ammonia. Chemistry in Nonaqueous Ionizing Solvents," Vol. I, Part 2, Wiley, New York, N. Y., 1963, p 228.

whereas ammonium chloride protonates the benzyl alkoxide and the resulting benzyl alcohol is rapidly reduced to the aromatic hydrocarbon before all the lithium is destroyed.

The results of this study, which are summarized in Table I, indicate the selectivity and synthetic utility of this simple procedure. It also has the advantages that the benzylidene ketones and aldehydes, if not commercially available, can be readily prepared by the Claisen-Schmidt reaction or related aldol condensations;⁵ and the organolithium reagents when not available can be generated *in situ* and yield similar results.

The methylation-reduction of benzylideneacetone, the last entry in Table I, is included because it represents a limitation of the procedure which is a direct consequence of the sequence of events. Lithium-ammonia reduction of the intermediate benzylidene

(5) A. T. Nielsen and W. J. Houlihan in "Organic Reactions," Vol. 16, A. C. Cope, Ed., Wiley, New York, N. Y., 1968, pp 1-438.

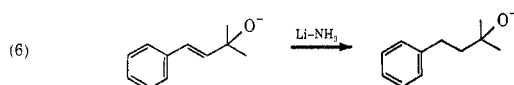
alkoxide forms an alkoxide which is not benzylic and consequently cannot be reduced further during the ammonium chloride quench.⁶ Hence the same product is formed using either quenching agent.

Experimental Section⁷

Alkylation-Reduction General Comments.—The entire reaction sequence was performed under a prepurified nitrogen atmosphere which is connected by a T tube to the assembly and an oil bubbler. All glassware was oven-dried, cooled to room temperature in a large box desiccator, and then quickly assembled. Phenyllithium (19.7% in ether-benzene) and methylolithium (5.1% in ether) were obtained from Foote Mineral Co. Phenyllithium was also generated *in situ* in the reaction vessel from bromobenzene and lithium foil in Et₂O. Anhydrous Et₂O was used directly from freshly opened containers. Anhydrous ammonia was distilled into the reaction vessel. Lithium wire (0.125 in., 0.01% Na, Ventron Corp.) was wiped free of oil and rinsed in petroleum ether just prior to use. All aromatic hydrocarbon and alcohol products gave satisfactory spectral and analytical data, and in some cases were compared with authentic samples. The methylation-reduction of benzylideneacetophenone (1) is described to illustrate the general procedure.

Methylation-Reduction of Benzylideneacetophenone (1).—To a solution of 7.4 mmol of MeLi in 15 ml of Et₂O in a metal-ammonia reaction vessel⁸ was added, dropwise and with stirring, 1.03 g (4.95 mmol) of benzylideneacetophenone (1) in 5 ml of Et₂O. After 1 hr *ca.* 20 ml of ammonia was carefully, to prevent excessive splattering, distilled into the mixture; this was then followed by the rapid addition of 175 mg (25 mg-atoms, eight pieces) of lithium wire. The mixture soon turned dark blue with red fringes.⁸

1,3-Diphenylbutane (6, Ammonium Chloride Quench).—To



(7) Spectral measurements were determined with the following instruments: ir, Perkin-Elmer Model 237; nmr, Varian Associates Model A-60; mass spectra, Perkin-Elmer Model 270 with a Varian Associates Model 620/i computer attachment. Gas chromatographic analyses (glpc) of the aromatic hydrocarbons (ammonium chloride quench) were performed on a Hewlett-Packard Model 5750 research chromatograph (flame detector) using a 6 ft × 0.25 in. (stainless steel) 10% Apiezon L on 60-80 Chromosorb W (AW, DMCS) column and the benzyl alcohols (sodium benzoate quench) on a Hewlett-Packard Model 7610 high-efficiency chromatograph (flame detector) using a 4 ft × 6 mm (all glass) 4% silicone gum rubber UCC-W-982 (methylvinyl) on 80-100 HP Chromosorb W (AW, DMCS) column. Column chromatography of the aromatic hydrocarbons was performed on neutral aluminum oxide (activity I) using petroleum ether (bp 38-58°) and chromatography of the alcohols was performed on neutral aluminum oxide (activity III) using petroleum ether and petroleum ether-Et₂O.

(8) Normally *ca.* 20 min elapsed before proceeding with the quenching step, although the time interval does not seem too critical.

the dark-blue mixture (red fringes) was cautiously added,⁹ with vigorous stirring, *ca.* 3 g of ammonium chloride until the mixture turned white (*ca.* 4 min) and the ammonia was allowed to evaporate. After the residue had been partitioned between aqueous NaCl and Et₂O, the organic phase was dried (MgSO₄), filtered, concentrated at water aspirator pressure at 40-50°, and analyzed (glpc). Following chromatography (neutral aluminum oxide, activity I; petroleum ether) 0.925 g (89%) of 1,3-diphenylbutane (6) was obtained as a colorless liquid: ir (film) 3080, 3060, 3030, 1600, 1495, 700 (aromatic); 2960, 2930, 2860, 1450, 1375 cm⁻¹ (CH₃, CH₂, CH); nmr (CCl₄, TMS) δ 1.22 (3 H, d, *J* = 7 Hz, CH₃), 1.6-2.1 (2 H, m, CH₂), 2.5 (2 H, t, *J* = 8 Hz, CH₂), 2.6 (1 H, apparent sextet, *J* = 7 Hz, CH), and apparent singlets at 7.14 (4 H, Ar) and 7.2 (6 H, Ar); mass spectrum *m/e* (rel intensity) 210 (M⁺, 14), 119 (11), 105 (100), 91 (61), and 77 (22).

Anal. Calcd for C₁₆H₁₈: C, 91.37; H, 8.63. Found: C, 91.39; H, 8.61.

This product was identical with that obtained by the phenylation-reduction (ammonium chloride quench) of benzylideneacetone (3).

1,3-Diphenyl-3-butanol (4, Sodium Benzoate Quench).—To the dark-blue mixture (red fringes) was cautiously added,⁹ with vigorous stirring, *ca.* 1.5 g of sodium benzoate until the mixture turned yellow (*ca.* 4 min) and then the ammonia was allowed to evaporate. Normal work-up (described above) and chromatography (neutral aluminum oxide, activity III; petroleum ether, petroleum ether-Et₂O) yielded 1.1 g (98%) of 1,3-diphenyl-3-butanol (4) obtained as a pale-yellow syrup exhibiting the following spectral properties: ir (film) spectrum was almost superimposable on that from product 6 except for additional bands at 3560, 3410 (broad), and 1120 cm⁻¹; nmr (CCl₄, TMS) δ 1.48 (3 H, s, CH₃), 1.7-2.1 (2 H, m, CH₂), a broad singlet, disappears when D₂O is added, at 2.4 (1 H, -OH) which is superimposed on a multiplet at 2.2-2.7 (2 H, CH₂), and a complex pattern at 6.8-7.4 (10 H, Ar); mass spectrum *m/e* (rel intensity) 226 (M⁺, 1), 211 (2), 209 (4), 208 (13), 193 (11), 121 (100), 107 (41), 106 (25), 105 (24), 91 (73), 77 (35), and 43 (99).

Anal. Calcd for C₁₆H₁₈O: C, 84.91; H, 8.02. Found: C, 84.72; H, 8.09.

This product was identical with that obtained by the phenylation-reduction (sodium benzoate quench) of benzylideneacetone (3).

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(9) The quenching agent was most conveniently introduced by attaching a glass tube filled with the salt to a side arm with tygon tubing. When the quenching agent is to be added the tube is raised and tapped gently to smoothly introduce the salt. Should this step start to become violent, the addition and the vigorous stirring should be momentarily halted to avoid an eruption.