Notes

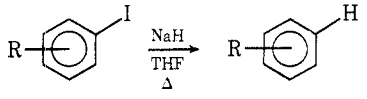
Reduction of Aryl Iodides with Sodium Hydride

Randall B. Nelson[1] and Gordon W. Gribble*[2]

Department of Chemistry, Dartmouth College, Hanover, New Hampshire 03755

Received December 5, 1973

We wish to report the hydrogenolysis of aryl iodides by a refluxing suspension of sodium hydride in dry tetrahydrofuran. The reaction typically proceeds in 85–95% isolated yield in 24 hr or less with a 3–10 molar excess of NaH in a small volume of THF.



Reduction by NaH has been previously observed in benzylic halides,[3] nonenolizeable carbonyl compounds,[4] *gem*-dihalocyclopropanes,[5] and some disulfides.[6] Most examples of NaH reduction have required dipolar aprotic media. For example, quinoline and isoquinoline are reduced to a mixture of 1,2- and 1,4-dihydroquinolines and 1,2-dihydroisoquinoline, respectively, in a warmed slurry of NaH and hexamethylphosphoramide (HMPA).[7]

The reaction with substituted aryl iodides is insensitive to the position of electron-donating ring substituents in the cases studied. For example, *o*-, *m*-, and *p*-iodoanisole with NaH provide anisole[8] in 93, 95, and 91% yield, respectively (Table I). Similarly, the isomeric *o*-, *m*-, and *p*-iodotoluenes afford toluene in >90% yield as determined by gc analysis of the crude reaction mixture. The reaction of *p*-iodotoluene is complete in less than 2 hr as indicated by precipitated NaI and gc analysis. Similarly, iodobenzene gives benzene in 84% yield as determined by gc. Previous reductions of aryl iodides have required lithium aluminum hydride.[9]

Table I
Reaction of Aryl Iodides with NaH in Refluxing THF[a]

Substrate	Product	% yield[b]	Registry no.
Iodobenzene	Benzene	84[c]	591-50-4
o-Iodotoluene	Toluene	91[c]	615-37-2
m-Iodotoluene	Toluene	97[c]	625-95-6
p-Iodotoluene	Toluene	100[c,d]	624-31-7
o-Iodoanisole	Anisole	93[e]	529-28-2
m-Iodoanisole	Anisole	95	766-85-8
p-Iodoanisole	Anisole	91[e]	696-62-8
o-Iodobenzoic acid	Benzoic acid	μ5[f,i]	88-67-5
m-Iodobenzoic acid	Benzoic acid	75[g,i]	618-51-9
p-Iodobenzoic acid	Benzoic acid	20[h,i]	619-58-9
o-Bromobenzoic acid	Benzoic acid	75[g,i]	88-65-3
α-Iodonaphthalene	Naphthalene	88[e]	90-14-2

[a] Reaction time of 24 hr unless specified (registry no. for NaH, 7646-69-7). [b] Crude isolated yield unless specified. [c] Yield determined by gc with internal standard (toluene or benzene). [d] 2 hr reaction time. [e] 48 hr reaction time. [f] 72 hr reaction time. [g] 8 day reaction time. [h] 6 day reaction time. [i] Expressed as a per cent composition of a mixture of product and starting material.

Halobenzoic acids are only slowly reduced with NaH, perhaps due to heterogeneity of the reaction, and mixtures of starting material and benzoic acid[8] are obtained with *o*-bromobenzoic acid, *o*-iodobenzoic acid, *m*-iodobenzoic acid, and *p*-iodobenzoic acid.

The reaction yields unrecognizeable products when the aryl ring is substituted with electron-withdrawing groups such as carbomethoxy or nitro. With *o*-bromonitrobenzene a bright scarlet color initially appears, perhaps indicative of a σ-complex, followed by rapid darkening of the reaction mixture.

Whereas α-iodonaphthalene is smoothly reduced to naphthalene with NaH in THF, α-chloro- and α-bromonaphthalene are inert to NaH even in refluxing dioxane.

Experimental Section

Melting points were determined in open capillaries with a Mel-Temp Laboratory Devices apparatus and are uncorrected. Infrared spectra were measured with Perkin-Elmer 137 or 337 instruments. Nmr spectra were obtained with a Perkin-Elmer R-24 spectrometer. Woelm alumina was used for column chromatography. Organic solutions were dried with anhydrous granular K_2CO_3 and concentrated *in vacuo* with a Büchi rotary evaporator.

Representative Procedure. Naphthalene from α-Iodonaphthalene. An oven-dried, three-neck flask equipped with a reflux condenser and magnetic stir bar was allowed to cool to room temperature under a stream of dry nitrogen. The flask was then cooled to 0° and charged with 125 ml of dry THF. NaH was prepared by washing ~2 g of NaH oil dispersion (Ventron Chemical Corp.) with 25 ml of dry pentane and filtering the solid NaH on a fritted disk. The light gray NaH powder was rapidly weighed and 1.08 g (0.0450 mol) was transferred to the reaction flask at 0° under N_2. After being stirred 3 min, 2.85 g (0.0112 mol) of α-iodonaphthalene was added and the mixture was refluxed for 48 hr. The reaction was worked up by cooling to 0° and adding 95% EtOH dropwise under N_2. The mixture was diluted with 250 ml of H_2O and extracted with anhydrous ether. (One should ensure the ether does not contain peroxides as these oxidize the iodide and cause a darkening of the product.) The ethereal extract was washed with aqueous $NaHSO_3$, then H_2O, and dried over anhydrous K_2CO_3. Filtration and concentration *in vacuo* gave 1.43 g (100%) of light yellow orange material. Chromatography over 20 g of activity III basic alumina with ether-pentane (1:1) provided 1.26 g (88%) of pure naphthalene as a colorless solid, identical with authentic material (mixture melting point, nmr, ir).

Acknowledgment. We are grateful to the National Science Foundation (GP-13374), Eli Lilly, Merck Sharp and Dohme, and the National Institutes of Health (CA-14237) for their generous financial support of our research program. We wish to thank Dr. Michael E. Garst for many interesting discussions.

References and Notes

(1) NDEA Predoctoral Fellow, 1971–1973.
(2) Recipient of a Public Health Service Research Career Development Award (1 KO4-23756) from the National Institute of General Medical Sciences, 1971–1976.
(3) P. Caubere and J. Moreau, *Tetrahedron*, **25**, 2469 (1969); *Bull. Soc. Chim. Fr.*, 1986 (1970); S. Bank and M. C. Prislopski, *Chem. Commun.*, 1624 (1970).
(4) F. W. Swamer and C. R. Hauser, *J. Amer. Chem. Soc.*, **68**, 2647 (1946); G. Darzens, *C. R. Acad. Sci.*, **224**, 570 (1947); P. Caubere and J. Moreau, *Bull. Soc. Chim. Fr.*, 3270, 3276 (1971).
(5) J. Moreau and P. Caubere, *Tetrahedron*, **27**, 5741 (1971).
(6) L. H. Krull and H. Friedman, *Biochem. Biophys. Res. Commun.*, **29**, 373 (1967).

(7) M. Natsume, S. Kumadaki, Y. Kanda, and K. Kiuchi, *Tetrahedron Lett.*, 2335 (1973).
(8) This material is identical with an authentic sample by ir and proton nmr.
(9) For a discussion, see H. O. House, "Modern Synthetic Reactions," 2nd ed, W. A. Benjamin, Menlo Park, Calif., 1972, p 100.

Formation of Carbon–Carbon Double Bonds by the Reaction of Vicinal Dihalides with Sodium in Ammonia[1]

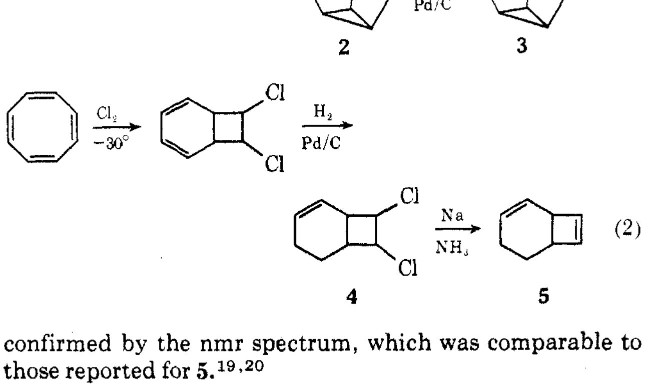
Evan L. Allred,* Boyd R. Beck,[2] and Kent J. Voorhees

Department of Chemistry, University of Utah, Salt Lake City, Utah 84112

Received October 10, 1973

Recently we had need to transform vicinal dihalides to structures containing carbon–carbon double bonds.[3] One of the reagents we considered to be a prime candidate for effecting the dehalogenations was sodium in liquid ammonia. In surveying the literature, we found reports of such a reaction to be rare.[4-7] Much to our surprise, the treatises which deal with synthetic methods and reagents fail to illustrate,[8,9] or in most cases even reference, the reaction.[10-17] We have found the reaction of vicinal dihalides with sodium in ammonia to be very valuable in our work, and we believe that there should be more general awareness of the usefulness of this dehalogenation method.

Two synthetic sequences which illustrate our use of the method are shown by eq 1 and 2. When dichloride **1** was treated with excess sodium in ammonia for 1 hr, tetracyclo[5.3.0.0^{2,10}.0^{3,6}]deca-4,8-diene (**2**) was obtained in essentially quantitative yield. The structure **2** was established unequivocally by partial hydrogenation to known compound **3** of 3,6-endo configuration.[18] A similar dechlorination of **4** likewise gave a high conversion to bicyclo[4.2.0]octa-2,7-diene (**5**). The product structure was confirmed by the nmr spectrum, which was comparable to those reported for **5**.[19,20]



The synthetic scope of the method was evaluated further with several simple vicinal dihalide systems. For example, treatment of 1,2-dichlorohexane, 1,2-dichlorocyclohexane, or 1,2-dichlorocyclooctane with sodium in ammonia for 1.5 hr gives >96% conversion to the corresponding alkene. Analogously, 1,2-dibromocyclohexane was transformed to cyclohexene (98%). When 1,2-dichlorocyclooctane was treated with sodium in ammonia for 10 min, a >95% conversion to cyclooctene was realized. We have not examined the question of the stereochemistry of the dehalogenations. However, an early mechanistic study indicates that the process is not stereospecific.[5,21]

It is often declared that dehalogenation of vicinal dihalides is of little synthetic value since the dihalides themselves are prepared from the alkenes.[12-14,16,23,24] Such statements are misleading in terms of synthetic usefulness. As illustrated by eq 1 and 2, dehalogenation can be an important part of a synthetic sequence which generates a structurally new double bond. Sodium in ammonia is an excellent reagent for this because the reaction is easily and rapidly completed, and the conversion to alkene is uniformly very high. For dehalogenation of **1** and **4** we found sodium in ammonia to be superior to the recently recommended arene–sodium reagents[22,25] in both convenience of procedure and in yield of isolated product.[3] It is clear that sodium in ammonia should be ranked among the best dehalogenating agents.[8-17,23-25]

Experimental Section[26]

4,5-Dichlorotetracyclo[5.3.0.0^{2,10}.0^{3,6}]dec-8-ene (1). The procedure used was a modification of the photochemical addition of benzene to cyclobutene.[18] A solution of 62.9 g (0.51 mol) of *cis*-3,4-dichlorocyclobutene[27] and 350 ml of benzene under a nitrogen atmosphere was irradiated (quartz) with a 450-W Hanovia medium-pressure mercury lamp for 20 hr. Progress of the reaction was followed by glpc (20% SE-30 on Chromosorb W, 15 ft × 0.125 in., programmed 70–130° at 6°/min). After this time the unreacted *cis*-3,4-dichlorocyclobutene and benzene were removed by vacuum distillation at 80° by gradually decreasing the pressure to 0.2 mm. This left a residue of 10.6 g of viscous brown oil. The distillate of reactants was again irradiated for 20 hr. A total of five of these cycles produced 46.8 g of crude photoadduct. Elution chromatography on 500 g of neutral alumina (pentane eluent) gave 19.1 g of **1** (31% based on the *cis*-3,4-dichlorocyclobutene consumed), mp 72.5–75°. An analytical sample was obtained by preparative glpc (15% FFAP on Chromosorb W, 10 ft × 0.375 in.): mp 77–78°; nmr (C_6D_6) δ 5.26 (d of d, 1 H), 5.02 (d of d, 1 H), 4.46 (apparent t, 1 H), 3.62 (br d, 1 H), 3.44 (apparent t, 1 H), 3.14 (m, 1 H), 2.68 (m, 1 H), 2.38 (apparent q, 1 H), 1.47 (apparent d of t, 1 H), 1.26 (apparent q, 1 H).

Anal. Calcd for $C_{10}H_{10}Cl_2$: C, 59.70; H, 5.01; Cl, 35.28. Found: C, 59.89; H, 4.88; Cl, 35.06.

Tetracyclo[5.3.0.0^{2,10}.0^{3,6}]deca-4,8-diene (2). A 4.0-g (0.174 g-atom) sample of freshly cut sodium (porcelain spatula) was added to 500 ml of dry ammonia which had been distilled from sodamide. To this stirred blue solution under a nitrogen atmosphere was added *via* a syringe 7.73 g (0.034 mol) of **1** in 75 ml of dry tetrahydrofuran. The reaction solution was stirred for 1 hr and then was quenched by cautiously adding ammonium chloride in small portions. Following this, 200 ml of ether and 800 ml of water were added. The aqueous mixture was extracted continuously with ether. The ether was removed from the dried extract ($MgSO_4$) by careful distillation, leaving 4.92 g (~98%) of **2**. A pure sample of **2** was obtained by preparative glpc (20% SE-30 on Chromosorb W, 10 ft × 0.375 in., 110°): ir (neat) 6.27 (C=C, cyclopentene),[28] 6.45 μ (C=C, cyclobutene);[28] nmr (C_6D_6) δ 6.18 (m, 1 H), 5.62 (d of d, 1 H), 5.50 (br d, 1 H), 5.00 (d of d, 1 H), 3.86 (m, 1 H), 3.70 (m, 1 H), 3.18 (apparent d of t, 1 H), 2.96 (apparent q, 1 H), 1.66 (apparent d of t, 1 H), 0.94 (apparent q, 1 H); high-resolution mass spectrum *m/e* 130.0790 (calcd for $C_{10}H_{10}$, *m/e* 130.0783).

Tetracyclo[5.3.0.0^{2,10}.0^{3,6}]dec-8-ene (3). A 40.1-mg (0.31 mmol) sample of **2** in 5 ml of ethyl acetate containing 30 mg of 5% palladium on carbon was partially reduced by the microhydrogenation procedure of Wiberg.[29] Stirring was stopped when