for 12 h. This resulted in the ylide **3** (48.6 g, 28% based on **5**) as light tan crystals. Crystallization from benzene–hexane gave an analytical sample: mp 187.5–188 °C; IR (KBr) ν_{max} 3040 (mw), 2980 (w), 2920 (mw), 2870 (w), 2810 (mw), 1527 (s), 1476 (m), 1431 (ms), 1387 (s), 1178 (mw), 1100 (s), 990 (w), 945 (m), 928 (m), 863 (m), 745 (m), 713 (ms), 691 cm^{-1} (s); UV (ether) λ_{max} 303 nm (ϵ 4300); ^1H NMR δ 7.50 (m, 15 H), 4.13 (br d, 1 H, J = 26 Hz), 3.93 (s, 2 H), 3.48 (s, 3 H); mass spectrum, m/e 348 (M^+, 1), 303 ($M^+ - CH_2OCH_3$, 100), 277 (Ph_3PCH_3, 4), 262 (PPh_3, 7).

Anal. Calcd. for $C_{22}H_{21}O_2P$: C, 75.85; H, 6.08; P, 8.89. Found: C, 75.86; H, 6.09; P, 8.91.

1,2-Bis(4-methoxy-3-oxo-1-*trans*-butenyl)benzene (11). A. From Ylide 3 and *o*-Phthaladehyde (10). A solution of *o*-phthaldehyde (**10**; 5.37 g, 0.04 mol) in dry dichloromethane (60 mL) was added dropwise with stirring to the ylide **3** (34.84 g, 0.1 mol) in dichloromethane (100 mL) in a flask protected from light. The reaction mixture was stirred at 15–16 °C for 15 min and was then refluxed for 20 h. Evaporation under reduced pressure led to a light brown semisolid residue, which was extracted thoroughly with boiling hexane. Repeated decantation and evaporation of the combined extracts under reduced pressure gave essentially pure dione **11** (10.91 g, 99.5%) as a viscous amber oil. The analytical sample was obtained by distillation at 0.1 mm: IR (film) ν_{max} 3060 (w), 3000 (w), 2940 (m), 2830 (m), 1705 (sh), 1690 (vs), 1615 (vs), 1595 (s), 1478 (m), 1440 (m), 1310 (ms), 1197 (s), 1120 (s), 980 (s), 933 (m), 756 (ms), 721 (ms), 696 cm^{-1} (m); UV (ether) 225 nm (ϵ 9400), 272 (21 000), 303 (15 000); ^1H NMR δ 8.03 (d, 2 H, J = 16 Hz), 7.50 (m, 4 H), 6.82 (d, 2 H, J = 16 Hz), 4.23 (s, 4 H), 3.48 (s, 6 H); mass spectrum, m/e 274 (M^+, 9), 229 ($M^+ - CH_2OCH_3$, 57), 201 ($M^+ - COCH_2OCH_3$, 100).

Anal. Calcd for $C_{16}H_{18}O_4$: C, 70.05; H, 6.61. Found: C, 70.18; H, 6.36.

B. From 1,2-Bis(2-formyl-*trans*-ethenyl)benzene (12).[3] Into a 250-mL five-neck round-bottom flask equipped with a mechanical stirrer, thermometer, nitrogen inlet, and two 50-mL dropping funnels was placed magnesium turnings (2.24 g, 92 mmol). The apparatus was flushed with nitrogen and flame dried. Mercuric chloride (90 mg) and dry tetrahydrofuran (45 mL) were added, and the mixture was stirred for 15 min. A small portion of a solution of freshly distilled chloromethyl methyl ether (6.5 g, 81 mmol) in dry tetrahydrofuran (20 mL) was added, and reaction was initiated by slight warming. A solution of the dialdehyde **12**[3] (2.32 g, 12.5 mmol) in dry tetrahydrofuran (20 mL) was then added dropwise with stirring at the same rate as addition of the remaining chloromethyl methyl ether solution (addition time ~20 min). If necessary, the reaction could be reinitiated by addition of a vigorously reacting mixture of magnesium and 1,2-dibromoethane. The reaction temperature was maintained below 35 °C at all times by means of an ice bath. The reaction mixture was stirred at 30 °C for 2.5 h and was then cooled to 0 °C. Saturated aqueous ammonium chloride solution (90 mL) was added in small portions, and the layers were separated. The aqueous phase was extracted with ether (3 × 40 mL) and the combined organic extracts were washed with brine. Drying over magnesium sulfate, evaporation under reduced pressure, and finally exposure to a 0.1-mm vacuum led to a diastereomeric mixture of the crude diol **13** (3.47 g, 100%) as a viscous yellow oil; ^1H NMR δ 7.30 (m, 4 H), 7.03 (d, 2 H, J = 16 Hz), 6.10, 6.00 (d, 2 H, J = 16 Hz), 4.53 (m, 2 H), 3.47 (m, 10 H), 2.83 (br s, 2 H).

Chromium trioxide (7.5 g, 75 mmol) was added in small portions to a stirred solution of dry pyridine (11.9 g, 150 mmol) in dry dichloromethane (70 mL) at 0 °C under nitrogen. The resulting suspension was stirred for 5 min at 0–5 °C, allowed to warm to room temperature, and then recooled to 0–5 °C. A solution of the crude diol **13** (3.47 g) in dry methylene chloride (30 mL) was added with stirring at this temperature during 5 min. The mixture was allowed to warm to room temperature and stirred for 1 h, and the supernanant liquid was filtered through a column of alumina (60 g, activity V). The residue was thoroughly extracted with dichloromethane and filtered through the column of alumina. The solvents were removed from the combined filtrates (200 mL) by evaporation under reduced pressure. Prolonged exposure of the residue to a 0.1-mm vacuum gave the diol **11** (2.48 g, 72%) as a viscous amber oil, the IR and ^1H NMR spectra of which were identical with those obtained by method A.

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Registry No. 3, 33513-55-2; **5**, 5878-19-3; **7**, 75522-04-2; **8**, 38568-50-2; **9**, 75522-05-3; **10**, 643-79-8; **11**, 75522-06-4; **12**, 61650-42-8; **13** (isomer 1), 75522-07-5; **13** (isomer 2), 75522-08-6.

Analysis of Organomagnesium and Organolithium Reagents Using *N*-Phenyl-1-naphthylamine

David E. Bergbreiter* and Ellen Pendergrass[1]

Texas A&M University, Department of Chemistry, College Station, Texas 77843

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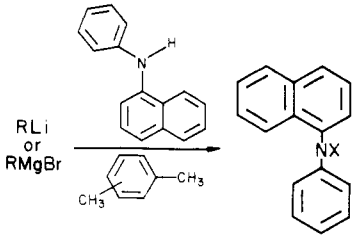
Accurate determination of the concentration of organolithium and organomagnesium reagents can be carried out by a number of procedures with varying degrees of generality.[2-6] The most useful of these procedures permits analysis of the reactive organometallic reagent of interest without interference from any alkoxide or hydroxide base which might be present as a result of adventitious oxidation or hydrolysis. Analytical procedures which directly measure the concentration of an organometallic reagent are thus significantly more useful than a simple total base titration with standard acid which does not distinguish between these possible other bases which might be present. Here we report a general procedure for such titrations in cases where other commonly used procedures have proven to be less effective. The procedure we have developed depends on a rapid acid–base reaction between a diarylamine and a reactive, basic organolithium or organomagnesium reagent (eq 1). Subsequent titration of the



(1)

X = Li or MgBr

resulting yellow-orange diarylamide with a xylene solution of *sec*-butyl alcohol to a cloudy white or colorless end point can then be used to determine the concentration of the organometallic species in question.

The principle requirements for successful application of the procedure we describe here are that the organometallic reagent to be titrated has to be substantially more basic than *N*-phenyl-1-naphthylamine and that no highly colored impurities be present in the organometallic solution to be titrated. Thus, all alkyllithium or -magnesium reagents we have tried can be successfully titrated but alkynyllithium or -magnesium reagents do not give reliable

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Table I. Comparative Titrations of Organomagnesium and Organolithium Reagents

organometallic reagent	solvent	titer, N method A[a]	method B[b]	method C[c]
n-C_4H_9Li[d]	hexanes	2.55	2.49	2.62
t-C_4H_9Li[e]	hexanes	2.16	2.13	2.10
CH_3MgCl	THF	2.50[f]	2.50	2.93
CH_3MgBr	Et_2O	2.90[f]	2.97[g]	3.08
$C_8H_{17}MgBr$	Et_2O	1.70[f]	1.71	1.83
sec-C_4H_9MgBr	Et_2O	0.88	0.80	1.42
sec-C_4H_9MgBr	Et_2O	0.81	0.80	0.89
C_6H_5MgBr	Et_2O	3.30[f]	3.20	3.76
$(sec$-$C_4H_9)_2Mg$	Et_2O	0.72[f]	0.70	1.05

[a] 1,10-Phenanthroline was used as an indicator (ref 2). [b] N-Phenyl-1-naphthylamine was used as an indicator (see text). [c] Total base determined by titration of an aqueous quench of an aliquot of the organometallic reagent to a phenophthalein end point using 0.1 N HCl. The variance between values for this titration and those of method A or B is due to other basic impurities. [d] Double titration of this organolithium reagent using dibromoethane (ref 3) showed this organolithium reagent to be 2.50 N. [e] Double titration of this organolithium reagent using dibromoethane (ref 3) showed this organolithium reagent to be 2.07 N. [f] Poorly defined end point had to be estimated. In some cases, addition of THF helped to clarify the end point of these 1,10-phenanthroline titrations. [g] Average of five titrations ranging from 2.91-3.07 M.

end points. Old solutions of vinylmagnesium bromide which produce colored solutions after a protic quench obscure the end point of this and other colorimetric procedures.

In our procedure, the relatively acidic N-phenyl-1-naphthylamine was used in either of two ways. First, a small amount of the diarylamine was added to a stock solution (0.05 M in N-phenyl-1-naphthylamine) of xylene containing a known concentration of *sec*-butyl alcohol (0.25 M). This alcohol–xylene indicator solution was then added to the organometallic reagent of interest in either an ethereal or hydrocarbon solvent until the yellow-orange color disappeared. Alternatively, a small amount (ca. 50 mg) of the diarylamide was added directly to a flask to which the organometallic reagent was then added. Subsequent titration with a 0.29 M xylene solution of *sec*-butyl alcohol until the yellow-orange color of the indicator had disappeared then determined the titer of the organometallic reagent.

Examples of the results obtained with this titration procedure are shown in Table I along with a comparison to other commonly used analytical procedures used to determine the concentration of typical organolithium and organomagnesium reagents. These data show the procedure we have developed is both general and reliable. The titers determined by our procedure vary by less than ±3%, apparently due to volumetric errors occurring during transfer of small volumes of organometallic reagent by syringe.[7]

Although there is no advantage to using this procedure in titrations of very common organolithium reagents like n-butyllithium, this procedure seems to be more useful in cases where alkylmagnesium halides are titrated. In such cases, the diarylamide procedure we describe consistently gives reliable end points while the best alternative method (the 1,10-phenanthroline procedure) gives end points of varying quality depending on the nature of the alkyl group attached to magnesium in the organomagnesium reagent.

(7) The reproducibility of measuring volumes by syringe, ±2% with calibrated syringes (ref 8, p 207), limits reproducibility of this technique as well as those described in ref 1–6 which also typically employ syringes to transfer solutions.

Experimental Section

Hydrocarbon and ethereal solvents were distilled from sodium/benzophenone prior to use. Organolithium and organomagnesium reagents were purchased from Aldrich Chemical Co. or prepared by using unexceptional procedures. The indicating acid, N-phenyl-1-naphthylamine, was purchased from Aldrich and purified prior to use by recrystallization from alcohol. Purified N-phenyl-1-naphthylamine can be kept for at least 1 year without significant discoloration in nitrogen-flushed bottles. Xylene solutions (0.005 M) turned yellow-brown during the same period, plausibly because of adventitious oxidation. Standard techniques for handling air-sensitive organometallic reagents were used throughout this work.[8]

Analysis of Methylmagnesium Bromide. To a flame-dried, 50-mL round-bottomed flask under nitrogen containing a magnetic stirring bar was added 2 mL of an ether solution of methylmagnesium bromide. This flask was then connected to a buret containing a xylene solution of N-phenyl-1-naphthylamine (0.005 M) and *sec*-butyl alcohol (0.25 M) by means of a hypodermic needle connected to a Luer fitting on the buret. While the flask was vented to a mineral oil bubbler, the titrant was added dropwise to a stirred solution. A yellow-orange color[9] which initially formed continued to deepen until at last enough *sec*-butyl alcohol had been added to react with all the amide and Grignard reagent. At this point the deep yellow-orange color disappeared and a cloudy white suspension formed. If more ether solvent was present initially the colored solution changed to give a water white solution. A modification of this procedure which avoids the necessity of storing xylene solutions of N-phenyl-1-naphthylamine has also proven successful. In this modified procedure, ca. 50 mg of N-phenyl-1-naphthylamine was first added to the flame-dried flask. Addition of a Grignard reagent then produced N-phenyl-1-naphthylamide which was titrated with 0.29 M *sec*-butyl alcohol in xylene as described above.

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Registry No. N-Phenyl-1-naphthylamine, 90-30-2; CH_3MgBr, 506-83-2; n-C_4H_9Li, 109-72-8; t-C_4H_9Li, 594-19-4; CH_3MgCl, 676-58-4; $C_8H_{17}MgBr$, 17049-49-9; sec-C_4H_9MgBr, 922-66-7; C_6H_5MgBr, 100-58-3; $(sec$-$C_4H_9)_2Mg$, 17589-14-9.

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(9) Lithium N-phenyl-1-naphthylamide has a λ_{max} at 440 nm while bromomagnesium N-phenyl-1-naphthylamide has a λ_{max} at 401 nm.

Synthesis of *cis*- and *trans*-7,8-Dihydrodiols of 7-Methylbenzo[*a*]pyrene

Peter P. Fu,* Ching-Cheng Lai, and Shen K. Yang†

Department of Health and Human Services, National Center for Toxicological Research, Jefferson, Arkansas 72079 and Department of Pharmacology, School of Medicine, Uniformed Services University of the Health Sciences, Bethesda, Maryland 20014

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We recently reported that a methyl substituent in a polycyclic aromatic hydrocarbon (PAH) does not necessarily block the enzymatic formation of a dihydrodiol at the methyl-substituted aromatic double bond.[1] This enzymatic reaction is now known to occur in vitro for many methylated PAH's in rat liver microsomal enzyme sys-

† Department of Pharmacology.