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LITHIATED TOLUNITRILES: PREPARATION AND REACTIONS

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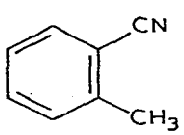
Summary

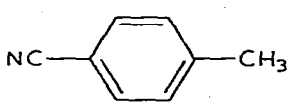
Metalation of *m*-tolunitrile has been achieved by means of lithium dimethylamide and lithium diisopropylamide in THF/HMPA to afford a new, synthetically useful organometallic reagent. *o*-Tolunitrile and the *p*-isomer also react with such bases to give the corresponding lithiated derivatives. Each of the lithiotolunitriles readily undergoes condensations with various electrophiles.

Introduction

o-Tolunitrile (I) and *p*-tolunitrile (II) have previously been metalated by sodium amide and potassium amide in liquid ammonia as evidenced by condensations with alkyl halides and other electrophiles [1—4]. On the other hand, attempts to metalate *m*-tolunitrile (III) by sodium amide in ammonia have been unsuccessful and only unidentified materials were obtained [3]. The use of stronger bases like organolithium reagents in such reactions has been precluded by their addition to the nitrile group; for example, I and n-butyllithium · TMEDA affords 2-methylvalerophenone (75%) [5]. Similarly, a variety of Grignard reagents have been reacted with I, II, and III to give ketones or imines [6]. Even potassium amide [7] and sodium amide [3,8] have been added to II under more strenuous conditions.



(I)



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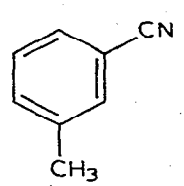


(III)

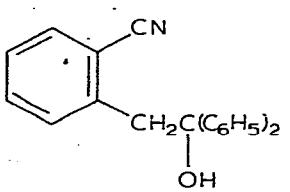
This paper describes successful metalations of I, II, and III by the strong basic reagents lithium dimethylamide (LDMA) and lithium diisopropylamide

(LDIPA) to afford the first examples of lithiated tolunitriles. More importantly, such reactions on III represent the first time this compound has been converted to an organometallic derivative thus opening a new synthetic route to substituted *m*-tolunitriles.

Results and discussion

Initially, the more acidic I and II were interacted with bases stronger than alkali amides to ascertain the extent of metalation of the methyl side-chain versus addition to the nitrile. Thus, I was first treated with n-butyllithium in THF/HMPA at —78° C, a temperature lower than that previously employed [5], to afford recovered I (69%), 2-methylvalerophenone (21%), and 1-amino-3-(2-methylphenyl)isoquinoline (2%). Since the amount of addition product was deemed too large, this base was not further studied. Incidentally, the isoquinoline arises from metalation of the methyl group and has been discussed elsewhere [9].

Next, I was treated with LDMA in THF/HMPA at —78° C to give I (83%); addition products were absent. That *o*-lithiomethylbenzonitrile was present in the above was demonstrated by repeating the reaction and adding benzophenone to give carbinol IV (53%). A related sequence involving I, LDIPA, and benzophenone also afforded IV (40%). Similar results were obtained by reacting II with LDMA and LDIPA in THF/HMPA at —78° C followed by benzophenone to give V in yields of 67% and 88%, respectively. Presumably, the smaller amount of metalation of I by LDIPA than by LDMA can be ascribed to a steric effect. In contrast, the larger amount of metalation of II by LDIPA is probably due to its increased basicity over that of LDMA. Carbinol V has previously been prepared (54%) using sodium amide as the metalating agent [2].



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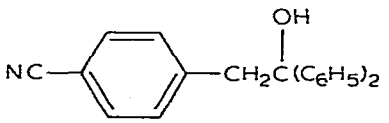
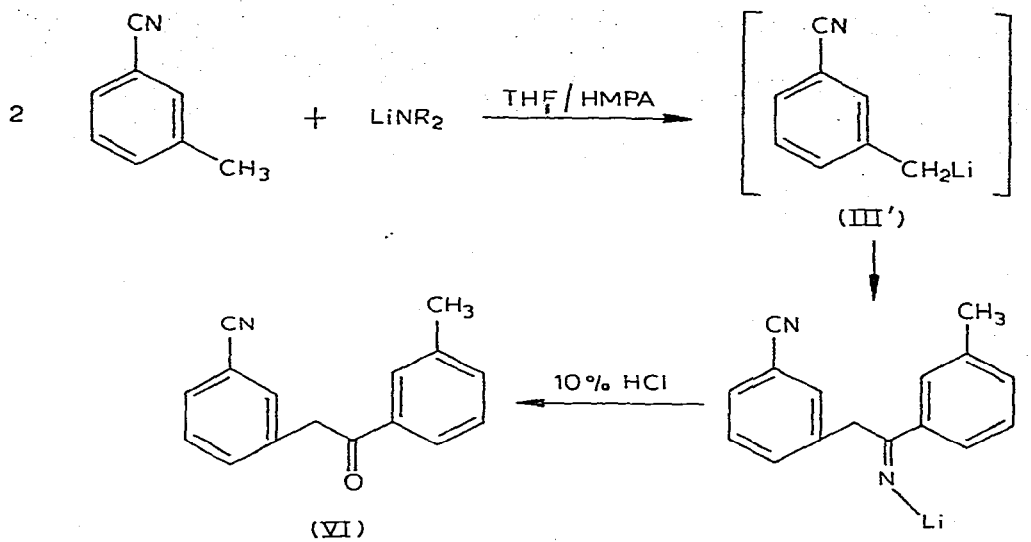


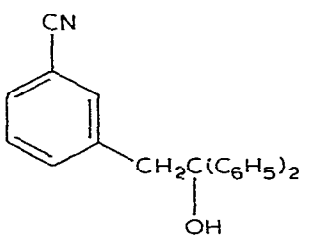
(V)

Attention was next directed to metalation of III by LDMA and LDIPA. Thus, III was treated with 0.5 equivalents of LDMA in THF-HMPA at —78° C and the reaction warmed to 65° C to give ketone VI (eq. 1). That the ketone which could only arise from the condensation of lithio salt III′ with III was obtained in a yield of 81% indicated that at least 81% of the LDMA had metalated III. A similar reaction between III and 0.5 equivalents of LDIPA at 25° C for only 5 min. also afforded VI (76%).

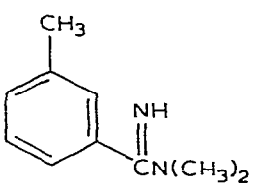
Equimolar amounts of III and LDMA in THF/HMPA were then reacted at —78° C followed by the addition of benzophenone. Surprisingly, instead of the expected carbinol VII, the reaction afforded III (37%), benzophenone (96%), and products arising from addition of LDMA to nitrile, namely amidine VIII (40%) and triazine IX (Ar = *m*-$CH_3C_6H_4$) (10%). Presumably, the amidine present in this case is a result of the law of mass action since neither VIII nor IX



were found when only 0.5 equivalents was employed. Similar products have been described in the reactions of benzonitrile and *p*-tolunitrile with LDMA in refluxing ethyl ether but yields were not reported [10]. Incidentally, a blank run on benzonitrile with LDMA in THF/HMPA at 25° C for 1 h gave amidine X (49%) and triazine IX (Ar = C_6H_5) (4%).



(VII)



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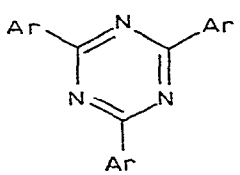

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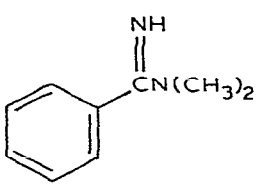
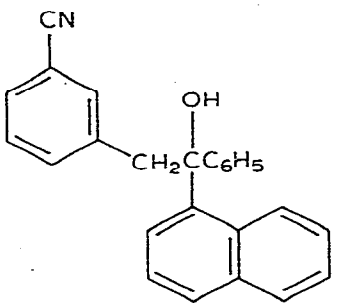


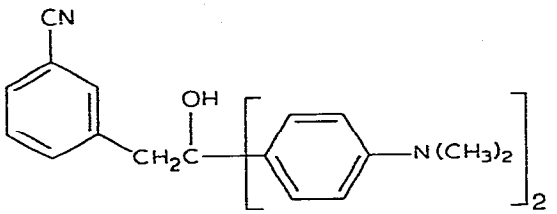
(X)

Since LDIPA has more steric bulk than LDMA, it was reacted with an equimolecular amount of III in anticipation that addition to the nitrile would be decreased. This was realized since subsequent reaction with benzophenone gave carbinol VII (28%); amidine and triazine side-products could not be detected. The yield of VII was increased to 41% by adding a solution of both III and

benzophenone in THF to LDIPA in THF/HMPA. The latter technique was also employed in the condensation of III′ with α-naphthyl phenyl ketone to give carbinol XI (39%). A related reaction of III′ with 4,4′-bis(dimethylamino)-benzophenone afforded XII (45%).

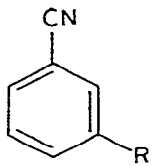


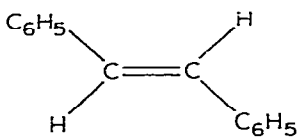
(XI)



(XII)

Organometallic III′ was also alkylated by n-propyl, n-pentyl-, and n-hexyl bromides to give XIII—XV (30—37%). A similar reaction using benzyl chloride, though, gave ketone VI (69%) arising from condensation of III′ with III and *trans*-stilbene (XVI) (87%); alkylated product like XIII—XV was absent. The formation of XVI is not surprising and is explained by the fact that III′ is a sufficiently strong base to metalate benzyl chloride rather than displace the chlorine. Of course, unreacted LDIPA could also effect this reaction, one that has been commonly encountered with alkali amides in ammonia [11].

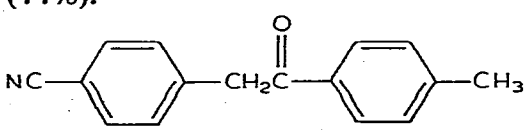




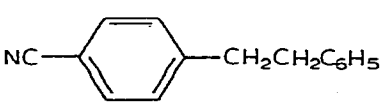
(XVI)

(XIII) R = n-C_4H_9
(XIV) R = n-C_6H_{13}
(XV) R = n-C_7H_{15}

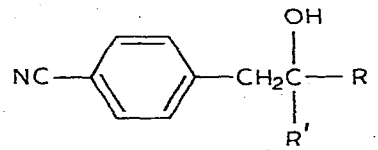
Because the condensation of α-lithio-*p*-tolunitrile (II′) prepared from II and LDIPA with benzophenone described earlier afforded V in substantially higher yields than previously realized [2], II′ was condensed with several other electrophiles using the current method. Thus, the addition of an extra equivalent of II to II′ gave ketone XVII (76%). Similarly, benzyl chloride afforded XVIII (75%) while *p*-chlorobenzaldehyde and phenyl pyridyl ketone gave XIX (76%) and XX (73%), respectively. Finally, chalcone afforded the 1,4-adduct XXI (77%).



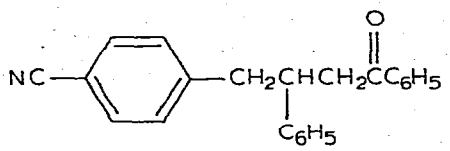
(XVII)



(XVIII)



(XIX) R = H, R′ = *p*-ClC$_6$H$_4$
(XX) R = C$_6$H$_5$, R′ = C$_5$H$_4$N



(XXI)

Conclusion

The isomeric tolunitriles clearly can be conveniently lithiated to afford organometallics that readily enter into condensation reactions. In the case of the *m*-derivative, the greatest problem encountered with the present procedure is incomplete metalation at the temperatures necessary to prevent complete self-condensation.

Experimental

Melting points were determined on a Thomas—Hoover Capillary Melting Point Apparatus and are uncorrected. All boiling points are uncorrected. Microanalyses were performed by Galbraith Laboratories, Inc. of Knoxville, Tennessee. Infrared spectra were recorded on a Perkin—Elmer 237B spectrophotometer and nuclear magnetic resonance spectra were obtained at 60 MHz on a Varian A-60 spectrophotometer using tetramethylsilane as an internal standard. n-Butyllithium was purchased from Apache Chemicals of Rockford, Illinois. Commercial anhydrous tetrahydrofuran was distilled from solutions containing calcium hydride after preliminary drying over calcium oxide. Commercial anhydrous HMPA was distilled from solutions containing calcium hydride and stored in septum fitted dark bottles under a positive pressure of purified argon. Solutions of LDMA and LDIPA were prepared in 300-ml, three-necked flasks equipped with a magnetic stirrer, constant pressure addition funnel, and a rubber septum by treating 0.025 mol of the amine in 10 ml of THF with 16.0 ml (0.025 mol) of 1.6 *M* n-butyllithium in hexane at 0°C followed, after 30 min by 4.5 g (0.025 mol) of HMPA.

Reaction of n-butyllithium · HMPA with o-tolunitrile

To a solution of n-butyllithium · HMPA complex prepared from 26 ml (0.040 mol) of 1.6 *M* n-butyllithium and 7.2 g (0.04 mol) of HMPA in 50 ml of THF at —78°C, was added 8.8 g (0.075 mol) of *o*-tolunitrile in 20 ml of THF. The solution was stirred for 30 min at —78°C and subsequently hydrolyzed with 100 ml of 10% hydrochloric acid. The layers were separated and the organic layer was washed with water, dried over calcium chloride, and concentrated to afford a yellow oil. The oil was distilled to yield 6.07 g (69%) of *o*-tolunitrile: b.p. 88—91°C/15 mmHg; lit. [12] b.p. 90°C/15 mmHg; n_D^{25} 1.5271; lit. [12] n_D^{25} 1.5272. The aqueous layer was made basic with potassium hydroxide pellets and subsequently extracted with three 25 ml-portions of diethyl ether. Work-up

as above gave a yellow oil which was chromatographed on a silica gel column using 4 : 6 diethyl ether/petroleum ether (b.p. 60—80°C) as eluent to afford 2.7 g (21%) of 2-methylvalerophenone; b.p. 97°C/2 mmHg; lit. [13] b.p. 97—98°C/2 mmHg; n_D^{20}1.5140; lit. [13] n_D^{20}1.5141; semicarbazone, m.p. 151—152°C; lit. [13] m.p. 151—152°C. 1-Amino-3-(2-methylphenyl)isoquinoline (0.2 g, 2%) was also obtained from the column: m.p. 124—125°C; lit. [14] m.p. 123.5—124.5°C. These products account for 92% of the *o*-tolunitrile.

Reactions of o-tolunitrile with LDMA and LDIPA; condensation with benzophenone

To a solution of 0.025 mol of LDMA at —78°C was added 2.9 g (0.025 mol) of *o*-tolunitrile in 15 ml of THF. The solution was stirred for 30 min at —78°C and subsequently hydrolyzed with 100 ml of 10% hydrochloric acid. The layers were separated and the aqueous layer was extracted with three 25 ml portions of diethyl ether. Work-up gave a yellow oil which was distilled to yield 2.5 g (83%) of *o*-tolunitrile: b.p. 89—90°C/15 mmHg; lit. [12] b.p. 90°C/15 mmHg; n_D^{25} 1.5272; lit. [12] n_D^{25} 1.5272.

The reaction was repeated except that the solution of I′ was treated during 5 min with 4.6 g (0.025 mol) of benzophenone in 15 ml of THF. The solution was stirred for 1 h at 25°C and then inversely hydrolyzed with 100 ml of 10% hydrochloric acid. The layers were separated and the aqueous layer was extracted with three 25 ml portions of diethyl ether. Work-up afforded a yellow gum which was recrystallized from dichloromethane/petroleum ether (60—80°C) to give 4.7 g (53%) of 1,1-diphenyl-2-(2-cyanophenyl)ethanol (IV): m.p. 106.5—107.5°C; NMR ($CDCl_3$) δ 2.4 (s, 1, OH), 3.9 (s, 2, CH_2), 7.2—7.65 (m, 14, ArH); IR (Nujol) 3500 cm^{-1} (OH); 2250 cm^{-1} (C≡N). Analysis found: C, 84.21; H, 5.67; $C_{12}H_{17}NO$ calcd.: C, 84.25; H, 5.72%.)

When the reaction was repeated using 0.025 mol of LDIPA, 3.0 g (40%) of IV was obtained which was identical to that above.

Preparation of 1,1-diphenyl-2-(4-cyanophenyl)ethanol (V) using LDMA and LDIPA

To a solution of 0.025 mol of the lithium dimethylamide · HMPA complex as prepared above at —78°C was added during 5 min 2.9 g (0.025 mol) of *p*-tolunitrile in 15 ml of THF. The solution was stirred for 30 min at —78°C and subsequently treated during 5 min with 4.6 g (0.025 mol) of benzophenone in 15 ml of THF. The solution was stirred for 1 h at 25°C and then hydrolyzed with 100 ml of 10% hydrochloric acid. The precipitate was removed by filtration and washed with water. The crude product was recrystallized from aqueous ethanol to afford 5.0 g (67%) of V: m.p. 185—186°C; lit. [2] m.p. 184—185°C.

The reaction was repeated using 0.025 mol of LDIPA to give 6.6 g (88%) of V, identical to that above.

Preparation of 3′-methyl-2-(3-cyanophenyl)acetophenone (VI) using LDMA and LDIPA

To a solution of 0.025 mol of LDMA at —78°C was added during 5 min 5.8 g (0.05 mol) of *m*-tolunitrile in 10 ml of THF. The solution was stirred at 65°C for 2 h and subsequently hydrolyzed with 100 ml of 10% hydrochloric

acid. The layers were separated and the aqueous phase was extracted with three 20 ml portions of diethyl ether. Work-up gave a yellow solid which was recrystallized from benzene/petroleum ether (b.p. 60—80°C) to afford 4.7 g (81%) of VI: m.p. 67—68°C; NMR ($CDCl_3$) δ 2.45 (s, 3, CH_3), 4.35 (s, 2, CH_2), 7.3—8.0 (m, 8, ArH); IR (Nujol) 2212 cm^{-1} (C≡N), 1680 cm^{-1} (C=O). (Analysis found: C, 81.82; H, 5.43. $C_{16}H_{13}NO$ calcd.: C, 81.68; H, 5.57%.)

The reaction was repeated using 0.5 equiv. of LDIPA for 5 min at 25°C to afford 2.2 g (76%) of VI which was identical to that above.

Attempted preparation of 1,1-diphenyl-2-(3-cyanophenyl)ethanol (VII) using LDMA

To a solution of 0.025 mol of LDMA at —78°C was added during 5 min 2.9 g (0.025 mol) of *m*-tolunitrile in 15 ml of THF. The solution was stirred for 15 min at —78°C and subsequently treated during 5 min with 4.6 g (0.025 mol) of benzophenone. The solution was stirred for 30 min at —78°C and then hydrolyzed with 100 ml of 10% hydrochloric acid. The layers were separated and the solid precipitate was removed by filtration. The solid was recrystallized from 95% ethanol to afford 0.3 g (10%) of 2,4,6-tri-(3-methylphenyl)-s-triazine: m.p. 149—151°C; NMR ($CDCl_3$) δ 2.6 (s, 3, CH_3), 7.45—7.55 (m, 2, ArH), 8.4—8.6 (m, 2, ArH); IR (Nujol) absorptions corresponding to NH and C≡N absent. (Analysis found: C, 81.90; H, 6.07; N, 11.85. $C_{24}H_{21}N_3$ calcd.: C, 82.02; H, 6.02; N, 11.96%.)

The aqueous layer was extracted with three 20 ml portions of diethyl ether. Work-up gave a yellow oil which was distilled to afford 1.6 g (37%) of *m*-tolunitrile: b.p. 84—85°C/10 mmHg; lit. [15] b.p. 84.5°C/10 mmHg; n_D^{20} 1.5250; lit. [15] n_D^{20} 1.5252, and 4.4 g (96%) of benzophenone: m.p. 48—49°C; lit. [16] m.p. 49°C.

The original aqueous layer was made basic with potassium hydroxide pellets and subsequently extracted with three 20 ml portions of diethyl ether. Work-up gave an oil which was distilled to yield 1.6 g (40%) of *N,N*-dimethyl-3-methylbenzamidine: b.p. 182—185°C/20 mmHg; n_D^{25} 1.5513; NMR (CCl_4) δ 2.35 (s, 3, CH_3), 2.85 (s, 6, CH_3), 6.3 (s, 1, NH), 7.0—7.5 (m, 4, ArH); IR (Neat) 3320 cm^{-1} (=NH).

Reaction of LDMA with benzonitrile

This reaction was effected as described immediately above using 2.6 g (0.025 mol) of benzonitrile. The resulting solution was stirred for 1 h at 25°C and subsequently worked-up as above to afford 0.8 g (31%) of benzonitrile: b.p. 70°C/10 mmHg; lit. [17] b.p. 69°C/10 mmHg; n_D^{20} 1.5289; lit. [17] n_D^{20} 1.5289; 1.8 g (49%) of *N,N*-dimethylbenzamidine (X): b.p. 51—53°C/0.05 mmHg; lit. [10] b.p. 52°C/0.05 mmHg; n_D^{25} 1.5516; lit. [10] n_D^{25} 1.5518; and 0.1 g (4%) of 2,4,6-triphenyl-s-triazine (IX): m.p. 232—234°C; lit. [10] m.p. 233—234°C.

Preparation of 1,1-diphenyl-2-(3-cyanophenyl)ethanol (VII) using LDIPA

To a solution of 0.025 mol of LDIPA at —78°C was added during 15 min 2.9 g (0.025 mol) of *m*-tolunitrile in 30 ml of THF. The solution was stirred for 1 h at —78°C and subsequently treated during 5 min with 4.6 g (0.025 mol) of

benzophenone in 15 ml of THF. The mixture was stirred for 1 h at 25°C and then inversely hydrolyzed with 100 ml of 10% hydrochloric acid. The layers were separated and the aqueous layer was extracted with three 20 ml portions of diethyl ether. Work-up gave a yellow gum which was recrystallized from aqueous ethanol to afford 2.1 g (28%) of VII: m.p. 155—157°C; NMR ($CDCl_3$) δ 2.3 (s, 1, OH), 3.6 (s, 2, CH_2), 7.1—7.6 (m, 14, ArH); IR (Nujol) 3450 cm^{-1} (OH), 2240 cm^{-1} (C≡N). (Analysis found: C, 84.31; H, 5.63. $C_{21}H_{17}NO$ calcd.: C, 84.25; H, 5.72%.)

When the above reaction was repeated by simultaneously adding 0.025 mol each of III and benzophenone from separate addition funnels, 2.0 g (26%) of VII was obtained.

When the reaction was repeated by adding a single solution containing 0.025 mol each of III and benzophenone, 3.08 g (41%) of VII was obtained.

Preparation of 1-α-naphthyl-1-phenyl-2-(3-cyanophenyl)ethanol (XI)

This reaction was effected as described immediately above using 5.8 g (0.025 mol) of α-naphthylphenylketone as the electrophile. After stirring for 1 h at 25°C, the reaction was worked-up to afford a yellow gum which was recrystallized from benzene/petroleum ether (b.p. 30—60°C) to yield 3.4 g (39%) of XI: m.p. 156—157°C; NMR ($CDCl_3$) δ 2.5 (s, 1, OH), 3.65 (s, 2, CH_2), 6.6—8.0 (m, 16, ArH); IR (Nujol) 3500 cm^{-1} (OH), 2230 cm^{-1} (C≡N). (Analysis found: C, 85.83; H, 5.53. $C_{25}H_{19}NO$ calcd.: C, 85.93; H, 5.48%.)

Preparation of 1,1-bis-(4-dimethylaminophenyl)-2-(3-cyanophenyl)ethanol (XII)

This reaction was effected by adding 6.7 g (0.025 mol) of solid 4,4'-bis-(dimethylamino)benzophenone to 0.025 mol of III' at —78°C. Work-up afforded a yellow solid which was recrystallized from benzene/petroleum ether (b.p. 30—60°C) to yield 4.3 g (45%) of XII: m.p. 166—167°C; NMR ($CDCl_3$) δ 2.39 (s, 1, OH), 2.91 (s, 12, CH_3), 2.49 (s, 2, CH_2), 6.5—6.77 (m, 4, ArH), 7.0—7.42 (m, 8, ArH); IR (Nujol) 3540 cm^{-1} (OH), 2225 cm^{-1} (C≡N). (Analysis found: C, 78.01; H, 6.93. $C_{25}H_{27}N_3O$ calcd.: C, 77.89; H, 7.06%.)

Alkylations of α-lithio-m-tolunitrile

(a). n-Propyl bromide. To a solution of 0.025 mol of LDIPA at —78°C was added during 5 min 2.9 g (0.025 mol) of *m*-tolunitrile in 30 ml of THF. The solution was stirred for 30 min at —78°C and subsequently treated during 5 min with 6.15 g (0.05 mol) of n-propyl bromide in 15 ml of THF. The solution was stirred for 1 h at 25°C and then inversely hydrolyzed with 100 ml of 10% hydrochloric acid. The layers were separated and the aqueous layer was extracted with three 20 ml portions of diethyl ether. Work-up gave a yellow oil which was distilled to afford 1.5 g (37%) of 3-n-butylbenzonitrile (XIII): b.p. 91—93°C/0.1 mmHg; n_D^{25} 1.5101; NMR (CCl_4) δ 0.8—1.85 (m, 7, $CH_2CH_2CH_3$), 2.5—2.8 (t, 2, CH_2), 7.2 (s, 4, ArH); IR (Neat) 2230 cm^{-1} (C≡N). (Analysis found: C, 83.17; H, 8.33. $C_{11}H_{13}N$ calcd.: C, 82.97; H, 8.23%.)

(b). n-Pentyl bromide. This reaction was effected as in part (a) using 7.5 g (0.05 mol) of n-pentyl bromide to give 2.0 g (30%) of 3-n-hexylbenzonitrile (XIV): b.p. 110—112°C/0.1 mmHg; n_D^{25} 1.5020; NMR (CCl_4) δ 0.85—1.91 (m, 11, $(CH_2)_4CH_3$), 2.5—2.84 (t, 2, CH_2), 7.41 (s, 4, ArH); IR (Neat) 2237

cm^{-1} (C≡N). (Analysis found: C, 83.16; H, 9.04. $C_{13}H_{17}N$ calcd.: C, 83.37; H, 9.15%.)

(c). n-Hexyl bromide. This reaction was effected as in part (a) using 8.2 g (0.05 mol) of n-hexyl bromide to give 1.7 g (34%) of 3-n-heptylbenzonitrile (XV): b.p. 120—122°C/0.1 mmHg; n_D^{25} 1.4950; NMR (CCl_4) δ 0.66—1.94 (m, 13, $(CH_2)_5CH_3$), 2.5—2.78 (t, 2, CH_2), 7.41 (s, 4, ArH); IR (Neat) 2225 cm^{-1} (C≡N). (Analysis found: C, 83.66; H, 9.45. $C_{14}H_{19}N$ calcd.: C, 83.53; H, 9.51%.)

(d). Benzyl chloride. This reaction was repeated using 3.15 g (0.025 mol) of benzyl chloride to afford a yellow gum which was recrystallized from methanol to yield 2.0 g (87%) of *trans*-stilbene: m.p. 124—125°C; lit. [11] m.p. 124.5—124.8°C. The recrystallization solvent was removed under reduced pressure to afford a yellow gum which was recrystallized from benzene/petroleum ether (b.p. 30—60°C) to give 2.0 g (69%) of a product (VI) identical in all respects to that obtained from the self-condensation of *m*-tolunitrile.

Condensations of α-lithio-p-tolunitrile

(a). With p-tolunitrile. To 0.025 mol of LDIPA in THF/HMPA at —78°C was added during 5 min 5.8 g (0.05 mol) of *p*-tolunitrile in 15 ml of THF. The solution was stirred for 1 h at 25°C and subsequently hydrolyzed with 100 ml of 10% hydrochloric acid. The layers were separated and the aqueous layer was extracted with three 20 ml portions of diethyl ether. The mixture was worked-up to yield a yellow solid. The crude product was recrystallized from chloroform/petroleum ether (b.p. 60—80°C) to afford 4.4 g (76%) of 4′-methyl-2-(4-cyanophenyl)acetophenone (XVII): m.p. 106—107.5°C; NMR ($CDCl_3$) δ 2.4 (s, 3, CH_3), 4.3 (s, 2, CH_2), 7.2—8.1 (m, 8, ArH); IR (Nujol) 2200 cm^{-1} (C≡N), 1670 cm^{-1} (C=O). (Analysis found: C, 81.90; H, 5.70. $C_{16}H_{13}NO$ calcd.: C, 81.68; H, 5.57%.)

(b). With benzyl chloride. This reaction was effected as above using 3.15 g (0.025 mol) of benzyl chloride as the electrophile. Work-up afforded a yellow oil which was distilled to yield 4.6 g (75%) of 1-(4-cyanophenyl)-2-phenylethane (XVIII): m.p. 41—42°C; lit. [3] m.p. 40—42.5°C.

(c). With 4-chlorobenzaldehyde. This reaction was effected as above using 3.5 g (0.025 mol) of 4-chlorobenzaldehyde as the electrophile. Work-up afforded a yellow solid which was recrystallized from benzene/petroleum ether (b.p. 30—60°C) to give 4.9 g (76%) of 1-(4-chlorophenyl)-2-(4-cyanophenyl)-ethanol (XIX): m.p. 120—122°C; NMR ($CDCl_3$) δ 2.25 (s, 1, OH), 3.0 (d, 2, CH_2), 4.9 (t, 1, CH), 6.85—7.75 (m, 8, ArH); IR (Nujol) 3475 cm^{-1} (OH), 2245 cm^{-1} (C≡N). (Analysis found: C, 69.79; H, 4.49. $C_{15}H_{12}ClNO$ calcd.: C, 69.91; H, 4.69%.)

(d). With phenyl-2-pyridyl ketone. This reaction was effected as above using 4.6 g (0.025 mol) of phenyl-2-pyridyl ketone as the electrophile. Work-up afforded a tan solid. The crude material was recrystallized from benzene/petroleum ether (b.p. 30—60°C) to give 5.5 g (73%) of 1-phenyl-1-(2-pyridyl)-2-(4-cyanophenyl)ethanol (XX): m.p. 133—135°C; NMR ($CDCl_3$) δ 3.65 (s, 2, CH_2), 5.8 (s, 1, OH), 7.0—7.85 (m, 12, ArH), 8.3—8.6 (m, 1, ArH); IR (Nujol) 3490 cm^{-1} (OH). (Analysis found: C, 79.70; H, 5.46. $C_{20}H_{16}N_2O$ calcd.: C, 79.98; H, 5.37%.)

(e). With chalcone. This reaction was effected as above using 5.2 g (0.025

mol) of chalcone as the electrophile. Work-up as above afforded a yellow solid which was recrystallized from ethanol to give 6.2 g (77%) of 1,3-diphenyl-2-(4-cyanophenyl)-1-butanone (XXI): NMR ($CDCl_3$) δ 2.9—3.9 (m, 5, CH_2CHCH_2), 7.1—7.75 (m, 12, ArH), 7.9—8.13 (m, 2, ArH); IR (Nujol) 2200 cm^{-1} (C≡N), 1670 cm^{-1} (C=O). (Analysis found: C, 84.74; H, 5.62. $C_{17}H_{19}NO$ calcd.: C, 84.89; H, 5.89%.)

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