



## **Mg/Triethylammonium Formate: A Useful System for Reductive Dimerization of Araldehydes into Pinacols; Nitroarenes into Azoarenes and Azoarenes into Hydrazoarenes**

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### **ABSTRACT**

Studies are reported which describes the effectiveness of triethylammonium formate in the presence of magnesium for the efficient intermolecular pinacol coupling using MeOH as solvent. Various aromatic carbonyls underwent smooth reductive coupling to give the corresponding 1,2-diols. A series of azo compounds were obtained by the reductive coupling of nitroaromatics while azo compounds were reduced to the corresponding hydrazoarenes by this system. There was no adverse effect on the other reducible and hydrogenolysable groups such as ether linkage, hydroxy and halogens. The reactions are clean, high yielding and inexpensive. All the reactions proceeded smoothly at ambient temperature.

**Key words:** Triethylammonium formate, Magnesium, Pinacol coupling, Reduction, Azo compounds.

### **INTRODUCTION**

Reduction of organic compounds is important synthetically both in the laboratory and in industry. In comparison with catalytic reduction using molecular hydrogen, transfer reduction using hydrogen donors has real and potential advantages<sup>1-3</sup>. Molecular hydrogen, a gas of low

molecular weight and therefore high diffusibility, is easily ignited and presents considerable hazards, particularly on the large scale; the use of hydrogen donors obviates these difficulties in that no gas containment is necessary, no pressure vessels are needed, and simple stirring of solutions is usually all that is required. Potentially, transfer methods could afford enhanced selectivity in reduction.

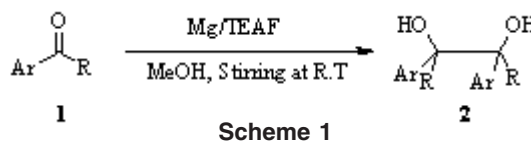
In the presence of hydrogenation catalysts, certain organic compounds can serve as the hydrogen source. The best hydrogen donors for heterogeneous catalytic transfer hydrogenation comprise of simple molecules such as cyclohexene<sup>4</sup>, 1,4-cyclohexadiene<sup>5</sup>, hydrazine<sup>6</sup>, formic acid<sup>7</sup> and formates<sup>8</sup>, phosphinic acid<sup>9-10</sup> sodium tetrahydroborate<sup>11</sup> sodium phosphinates<sup>12</sup> and indoline<sup>13</sup>. The efficiency of alkylammonium formates as a hydrogen donor in the palladium-catalyzed reductive dimerization of conjugated dienes has been studied by Roffia *et. al.*,<sup>14</sup>.

Triethylammonium formate is successfully used for the reductive dehalogenation of aromatic halides and nitro compounds in presence of Pd/C and Pt/C respectively<sup>15</sup>. It is also worth to note that triethylammonium formate is known for the reduction of mono and dinitro compounds,  $\alpha$ ,  $\beta$ -unsaturated carbonyl compounds and acetylenes in presence of palladium<sup>16</sup>. Later the same system was utilized for the reduction of acetylenes to cis-monoenes and hydrogenolysis of tertiary allylic amines<sup>17</sup>. Recently, D. C. Gowda *et. al* have reported the facile synthesis of azo compounds from aromatic nitro compounds using ammonium acetate catalyzed by lead<sup>18</sup>.

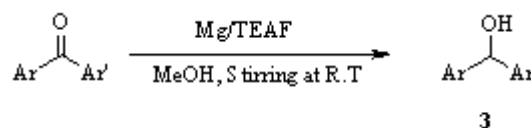
## RESULTS AND DISCUSSION

Very recently we found that hydrazinium sulfate in presence of magnesium for the rapid generation of arylhydroxylamines in water<sup>19</sup>. We also have used hydrazinium formate as an efficient reagent for the selective protection of carbonyl compounds as azines without any catalyst<sup>20</sup>. The effectiveness of both hydrazinium sulfate, hydrazinium formate and the utility of triethylammonium formate described above, prompted us to examine triethylammonium formate for possible organic transformation. Also to continue the research programme in developing methods for organic transformations employing inexpensive metals in combination with easily available reagents<sup>21</sup>, we thought it would be useful to investigate the reduction of carbonyl compounds in presence of magnesium and to better define the usefulness of triethylammonium formate, however we observed the pinacolization of carbonyl compounds as shown in Scheme 1. Pinacolization of benzaldehyde **1a**, an aromatic aldehyde was

studied initially as a representative example to optimize this reaction.

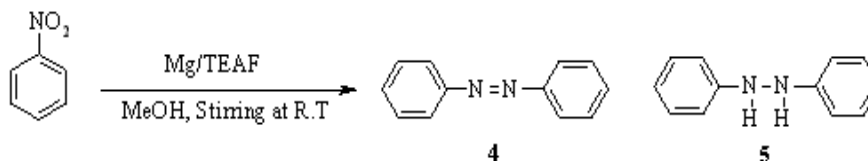


To a vigorously stirred suspension of 1.5 equivalent triethylammonium formate, freshly distilled benzaldehyde (1.06 g, 10 mmol) in methanol (5 mL) was added followed by commercial magnesium turnings (1.1 eq) and stirring was continued at room temperature to recover the corresponding pinacol. <sup>1</sup>H NMR (CDCl<sub>3</sub>):  $\delta$  2.33 (s, 2H, OH), 4.78 (s, 2H, PhCH-), 7.20–7.27 (m, 10H, Ar); m/z (%): 214 (1.6), 180 (2.8), 167 (2.0), 108 (88.00), 107 (100.00) 79 (82.40), 77 (48.00); IR (KBr): cm<sup>-1</sup> 3300–3529. This result prompted us to check other substituted aromatic aldehydes and ketones for the suitability of the reaction and found that benzaldehyde, substituted benzaldehydes furfuraldehyde and acetophenones to give the corresponding 1,2-diols. The substituents to benzaldehyde such as CH<sub>3</sub>, OCH<sub>3</sub>, Cl, and Br were unaffected and gave the desired products. The reactions of substituted araldehydes by the present method have been found to be sensitive to the electronic and steric effects of the substituents. The electron donating (inductive and mesomeric) groups seem to decrease the extent of conversion. Further, an attempt for pinacolization of hindered ketones such as benzophenone and substituted benzophenones with this system failed and were reduced to the corresponding benzhydrols as shown in Scheme 2 and the results are presented in table 1 (entries 3a-c). Treatment of diaryl ketones with this system for 1.5-2 h afforded the corresponding benzhydrols with 40% yield. When this reaction was carried out in the presence of 2 equiv. of triethylammonium formate with 2 equiv. of Mg, the yield improved to 55-62%.



It is interesting to note that, when nitrobenzene is subjected for the above reaction condition, we could observe the rapid change in colour from colourless to orange colour and

analyses revealed the formation of azobenzene with a trace amount of hydrazobenzene as shown in Scheme 3 and the method was extended to the reductive coupling of various substituted



Scheme 3:

Table 1: Rapid pinacolization stirring at 25 °C using Mg/TEAF-MeOH

Entry	Ar	R	Reaction Time/min	Yield (%) <sup>2a</sup>	Yield (%) <sup>3a</sup>
2a	C <sub>6</sub> H <sub>5</sub>	H	25	86	0
2b	4-ClC <sub>6</sub> H <sub>4</sub>	H	20	81	0
2c	3-ClC <sub>6</sub> H <sub>4</sub>	H	20	76	0
2d	2,4-ClC <sub>6</sub> H <sub>4</sub>	H	20	77	0
2e	3-BrC <sub>6</sub> H <sub>4</sub>	H	20	68	0
2f	Furyl	H	20	74	0
2g	4-CH <sub>3</sub> C <sub>6</sub> H <sub>4</sub>	H	25	74	0
2h	4-CH <sub>3</sub> OC <sub>6</sub> H <sub>4</sub>	H	35	62	0
2i	C <sub>6</sub> H <sub>5</sub>	CH <sub>3</sub>	30	71	Trace
2j	4-ClC <sub>6</sub> H <sub>4</sub>	CH <sub>3</sub>	25	65	Trace
2k	4-CH <sub>3</sub> OC <sub>6</sub> H <sub>4</sub>	CH <sub>3</sub>	30	62	Trace
2l	Cinnamaldehyde		30	67	0
3a	C <sub>6</sub> H <sub>5</sub>	C <sub>6</sub> H <sub>5</sub>	35	0	58
3b	4-CH <sub>3</sub> C <sub>6</sub> H <sub>4</sub>	C <sub>6</sub> H <sub>5</sub>	45	0	55
3c	4-ClC <sub>6</sub> H <sub>4</sub>	C <sub>6</sub> H <sub>5</sub>	45	0	62

<sup>a</sup>Characterized by <sup>1</sup>H NMR spectroscopy, IR and on GC with authentic samples.

Table 2: Reductive coupling of nitroaromatics to azo arenes using Mg/TEAF-MeOH

Entry	Nitro compounds	Reaction time (min)	Product 4	Yield (%)	Melting point (°C)	
					Found	Lit <sup>20</sup>
a.	Nitrobenzene	45	Azobenzene	93	68	68
b.	2-Methylnitrobenzene	80	2,2'-Dimethylazobenzene	89	56	55
c.	3-Methylnitrobenzene	80	3,3'-Dimethylazobenzene	90	65	54-55
d.	4-Methylnitrobenzene	65	4,4'-Dimethylazobenzene	90	142-144	144-145
e.	2-Methoxynitrobenzene	85	2,2'-Dimethoxyazobenzene	85	142-143	143
f.	4-Methoxynitrobenzene	80	4,4'-Dimethoxyazobenzene	88	158-159	160
g.	4-Ethoxynitrobenzene	80	4,4'-Diethoxyazobenzene	85	156-158	157-159
h.	2-Chloronitrobenzene	45	2,2'-Dichloroazobenzene	80	136-137	137
i.	3-Chloronitrobenzene	45	3,3'-Dichloroazobenzene	82	100-102	101
j.	4-Chloronitrobenzene	30	4,4'-Dichloroazobenzene	85	183-186	185

**Table 3: Reduction of azo compounds to hydrazoarenes using Mg/TEAF-MeOH**

Entry	Nitro compounds	Reaction time (min)	Product <sup>5</sup>	Melting point (°C)	
				Found	Lit <sup>20</sup>
a.	Azobenzene	25	Hydrazobenzene	124-125	126
b.	2,2'-Dimethylazobenzene	35	2,2'-Dimethylhydrazobenzene	162-164	165
c.	3,3'-Dimethylazobenzene	25	3,3'-Dimethylhydrazobenzene	38	38
d.	4,4'-Dimethylazobenzene	25	4,4'-Dimethylhydrazobenzene	133-134	134
e.	2,2'-Dimethoxyazobenzene	40	2,2'-Dimethoxyhydrazobenzene	99-100	102
f.	2,2'-Dihydroxyazobenzene	35	2,2'-Dihydroxyhydrazobenzene	147-149	148
g.	4,4'-Diethoxyazobenzene	35	4,4'-Diethoxyhydrazobenzene	84-85	86
h.	2,2'-Diethoxyazobenzene	25	2,2'-Diethoxyhydrazobenzene	87-88	89
i.	2,2'-Diethoxyazobenzene	20	3,3'-Diethoxyhydrazobenzene	118-120	119
j.	4,4'-Dichloroazobenzene	20	4,4'-Dichlorohydrazobenzene	122-123	123-24

nitrobenzenes to the corresponding azoarenes and the reduction of azoarenes to the respective hydrazoarenes as shown in Table 2 and Table 3.

### EXPERIMENTAL

All carbonyl compounds and substituted nitrobenzenes were of commercial grade; commercially available reagents and solvents were used throughout and purified before use. Yields refer to the isolated products after purification. Analytical TLC performed on precoated aluminum plates with Merck silica gel 60 F-254 as the adsorbent. The developed plates were air dried and irradiated with UV light. GC analyses were performed on a SHIMADZU GC-MS QP 5050A instrument. IR spectra were recorded on NICOLET 400D FT-IR Spectrometer. The <sup>1</sup>H NMR spectra were recorded on Bruker 300 MHz spectrometer as CDCl<sub>3</sub> solutions with TMS as internal standard.

#### General procedure for the rapid pinacolization

To a vigorously stirred suspension of triethylammonium formate (15 mmol), aromatic aldehyde/arylmethylketone (10 mmol) in aqueous methanol (5 mL) was added followed by magnesium turnings (10 mmol). After the completion of the reaction, the reaction mixture was filtered and the residue was washed with water, ethyl acetate (2 × 10 ml). The filtrate was diluted with water (25 ml) and repeatedly extracted with ethyl acetate (3 × 15 ml). The combined organic

extracts and washings were washed with water (2 × 10 ml), dried over anhydrous sodium sulfate. Solvent removal under reduced pressure gave a white solid, which was further purified by recrystallization using dichloromethane and light petroleum (40-60°C) to get pinacol as white solid.

#### Typical procedure for the reduction of benzophenone

To a stirred solution of triethylammonium formate (15 mmol), magnesium turnings (12 mmol) was added the benzophenone (10 mmol) in methanol (5 mL) at room temperature and the resulting mixture was stirred for the appropriate time (Table 1). After the complete disappearance of the starting material, the resulting mixture was filtered and washed with diethyl ether. The filtrate was treated with saturated aqueous sodium hydrogen carbonate. The filtrate was extracted with ethyl acetate. Evaporation of the solvent followed by treatment of the residue with anhydrous sodium sulfate at room temperature afforded the benzhydrol.

#### Typical procedure for the reductive dimerization of nitrobenzene into azobenzene

To a solution of triethylammonium formate (15 mmol), taken in a round bottomed flask, nitrobenzene (10 mmol) in methanol (15 mL) followed by magnesium turnings (12 mmol) were added and stirred at room temperature (25 °C). After the completion of the reaction (monitored by TLC), the reaction mixture was filtered through celite pad,

washed with diethyl ether. The filtrate was washed successively with saturated brine solution, water, dried over anhydrous sodium sulfate. Solvent removal and silica gel column chromatography gave azoarene.

#### Typical procedure for the reduction of azobenzene into hydrazobenzene

A mixture of azobenzene (182 mg, 1 mmol), triethylammonium formate (15 mmol), magnesium turnings (10 mg atom) and methanol (5 mL) in a round bottomed flask was stirred at room temperature (25°C). After the complete disappearance of the color of the starting material (orange to colourless), the reaction mixture was filtered through a Celite pad and washed with little diethyl ether. The combined filtrates and washings were evaporated under *in vacuo*. The residue was purified either by preparative TLC or column chromatography to get hydrazobenzene (0.175 g, 95 %).

#### CONCLUSION

In summary, we have utilized triethylammonium formate for the effective preparation of pinacols which have wide range of utility. For example, a) 1,2-diols are useful synthons for a variety of organic synthesis<sup>24</sup> b) constitutes an important method for the formation of carbon-carbon bonds<sup>25</sup> c) frequently have been utilized as auxiliaries in asymmetric synthesis<sup>26</sup> d) in the synthesis of HIV-protease inhibitors and some natural products such as taxol<sup>27</sup>. This system is extended to the reduction of diaryl ketones to the corresponding benzhydrols, reductive dimerization of nitroaromatics to the corresponding azoarenes and azoarenes into hydrazoarenes in high yields. The advantages of this method are readily available and easily accessible reagents, works at ambient temperature which avoids the formation of olefin in case of formation of pinacols, reaction completed in shorter durations compared to the previous procedures and non requirement of inert atmosphere and ultrasonic conditions.

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