4-(Nitro)-diphenylammonium triflate(NDPAT) catalysed esterification of carboxylic acids with alcohols

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4-(Nitro)-diphenylammonium triflate(NDPAT) efficiently catalysed the esterification between equimolar amounts of carboxylic acids and alcohols in good yield under mild reaction conditions.

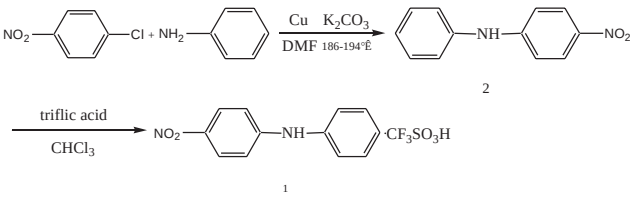
Keywords: 4-(nitro)-diphenylammonium triflate, esterification

The esterification of carboxylic acids with alcohols is an important reaction in organic synthesis.[1] Although several methods have been developed, a large excess of either the carboxylic acid or alcohol and/or dehydrating reagent are used to give esters in high yield.[2-14]

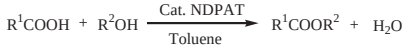
Recently, Wakasugi reported the esterification of equimolar amounts of carboxylic acids and alcohols catalysed by diphenylammonium triflate(DPAT) in good to excellent yields under mild reaction conditions.[15] Likewise, polymer-supported DPAT efficiently catalysed the reactions.[16] Faced with sterically hindered acids and alcohols, the same reaction was carried out in fluorous media.[17] In comparison with several amine triiflates, it seemed that with decreasing the basicity of the counter amine part, the scope of the esterification seemed to be higher.[15,16] The results encouraged us to investigate the reactivity of a new catalyst, 4-(nitro)-diphenylammonium triflate(NDPAT)(**1**) and its application in esterification. The NDPAT should be more active than DPAT because NDPA is less basic than DPA because of the electron withdrawing nitro substituent.

The preparation of the catalyst is described in Scheme 1. Using the Goldberg synthesis, the condensation of 4-nitrochlorobenzene with aniline in the presence of powder copper afforded 4-(nitro)-diphenylamine(**2**). The NDPAT was readily prepared by treating **2** with triflic acid.

The esterification reaction catalysed by NDPAT was performed between equimolar amounts of carboxylic acids and alcohols (Scheme 2). The results were listed at Table 1. Only 1 mol% of NDPAT was sufficient for benzeneproponic acid to react with primary alcohols(entries 3–7). While sterically crowded secondary alcohols just gave moderate yield (entry 8). Benzoic acid (entries 9–11) required 5 mol% of NDPAT with a prolonged reaction time. The water formed during the reaction was not removed. What is more, the yield



Scheme 1



Scheme 2

was not influenced by additional 72mg (4mmol) water (entry 12). When there was a large excess of water (360mg, 20mmol) in the reaction system, the result was still good (entry 13).

In conclusion, from the viewpoint of green chemistry NDPAT possesses a series of merits including air and water-stability. It is cheap, possesses low toxicity, and easy to handle. The operation of esterification is quite simple which demands no dehydration reagents or equipment. This catalytic system should be useful as environmentally and industrially ideal condensation in the future.

Experimental

All melting points recorded are uncorrected open capillary measurements. IR spectra were recorded on an Avatar 370 FT-1 R spectrophotometer. ^{1}H NMR spectra were recorded on a Bruker AC-80 400MHz instrument using tetramethyl silane(TMS) as internal standard. MS spectra were recorded on a HP5989B spectrophotometer.

Preparation of NDPAT: A mixture of 15.8 g (0.1 mol) 4-nitrochlorobenzene, 27.9 g (0.3 mol) aniline, 5.5 g (0.066 mol) DMF, 9.7 g (0.07 mol) potassium carbonate and 1.0 g powder copper

Table 1 Esterifications mediated by NDPAT[a]

Entry[b]	R^1COOH	R^2OH	NDPAT/mol%	Time/h	Yield[c]/%
3	$PhCH_2CH_2COOH$	$CH_3(CH_2)_3CH_2OH$	1	8	94
4	$PhCH_2CH_2COOH$	$CH_3(CH_2)_4CH_2OH$	1	8	94
5	$PhCH_2CH_2COOH$	$CH_3(CH_2)_5CH_2OH$	1	8	98
6	$PhCH_2CH_2COOH$	$CH_3(CH_2)_6CH_2OH$	1	8	96
7	$PhCH_2CH_2COOH$	$PhCH_2CH_2OH$	1	10	96
8	$PhCH_2CH_2COOH$	$CH_3CH(OH)(CH_2)_5CH_3$	5	16	76
9	PhCOOH	$CH_3(CH_2)_5CH_2OH$	5	30	95
10	PhCOOH	$CH_3(CH_2)_6CH_2OH$	5	30	94
11	PhCOOH	$PhCH_2CH_2OH$	5	30	95
12[d]	PhCOOH	$PhCH_2CH_2OH$	5	30	95
13[e]	PhCOOH	$PhCH_2CH_2OH$	5	30	82

[a]In toluene at 80°C. Molar ratio / R^1COOH : R^2OH = 1:1.
[b]All compounds were confirmed by ^{1}H NMR and MS.
[c]Isolated yields.
[d]72mg (4mmol) water was charged into the reaction system.
[e]360mg (20mmol) water was charged into the reaction system.

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were charged into a 100 ml 3-neck flask equipped with a Dean-Stark apparatus. The reaction mixture was boiled for 4 hours. During this time the boiling temperature increased from 186 to 194°C and a little water was distilled off as a water-aniline azeotrope. After cooling, the mixture was filtered off and washed with a small amount of aniline. Compound 2 (10.5 g, 49%) was obtained after evaporation of the solvent. Recrystallisation from ethanol gave yellow prisms, m.p. 130–133°C (literature[18] 129–133°C). IR(KBr, ν/cm^{-1}): 3341, 1604, 1585, 1540, 1524, 1495, 1482, 1303, 1186, 1112, 750. Triflic acid 1.5g(7mmol) was added to a solution of 1.05 g (7 mmol) 2 in chloroform (20 ml) at room temperature and the mixture was stirred for 0.5 hour. Evaporation of the solvent gave the crude product, which was washed with hexane (30 ml) to give a pure 1 (2.5 g, 98%) as yellow crystals (m.p. 114–116°C). IR(KBr, ν/cm^{-1}): 3342, 1605, 1586, 1541, 1525, 1496, 1483, 1303, 1185, 1110, 1034, 748. ^{1}H NMR(400MHz, d-DMSO): δ 9.29(s, 1H, NH), 8.09(d, *J*=9.2Hz, 2H, Ph–H), 7.38(t, *J*=7.8Hz, 2H, Ph–H), 7.26(t, *J*=9.1, 2H, Ph–H), 7.20(d, *J*=9.2Hz, 2H, Ph–H), 7.11(t, *J*=7.6Hz, 1H, Ph–H), 7.06 (d, *J*=9.1Hz, 2H, Ph–H). MS(*m/z*): 214(100.00), 167(99.62), 69(83.57), 57(46.85), 65(39.25), 168(38.92), 71(31.08), 43(30.83). Found: C 43.19%, H 3.11%, N 7.73%, Calculated: C 42.86%, H 3.04%, N 7.69%.

General esterification procedures: 3-Phenylpropionic acid (300 mg, 2 mmol), *n*-hexanol (204 mg, 2 mmol) and NDPAT (7.3 mg, 0.02 mmol) were heated(80°C) in toluene (10 ml) for 8 hours. Evaporation of the toluene under reduced pressure gave the crude material, which was purified by column chromatography (hexane:ethyl acetate = 10:1) to give the desired carboxylic acid ester (441 mg, 94%).

Compound **3**: ^{1}H NMR(400MHz, $CDCl_3$): δ 7.30–7.17 (m, 5H, Ph–H), 4.06 (t, *J*=6.3Hz, 2H, O–CH_2), 2.95 (t, *J*=7.8Hz, 2H, Ph–CH_2), 2.62 (t, *J*=7.8Hz, 2H, CO–CH_2), 1.60 (dd, *J*=7.0Hz, 2H, Me–CH_2), 1.35–1.26 (m, 4H, 2CH_2), 0.89 (t, *J*=6.85Hz, 3H, CH_3). MS(*m/z*): 221(M+1$^+$, 44.83), 104(100.00), 91(60.99), 105(44.00), 41(41.58), 43(41.08), 133(28.52), 77(17.12).

Compound **4**: ^{1}H NMR(400MHz, $CDCl_3$): δ 7.29–7.17 (m, 5H, Ph–H), 4.05(t, *J*=6.7Hz, 2H, O–CH_2), 2.95 (t, *J*=7.8Hz, 2H, Ph–CH_2), 2.62 (dd, *J*=7.8Hz, 2H, CO–CH_2), 1.62–1.55 (m, 2H, Me-CH_2), 1.31 (s, 6H, 3CH_2), 0.89 (t, J=6.8Hz, 3H, CH_3). Lit[19]: ^{1}H NMR (300MHz, $CDCl_3$): δ 0.88 (t, *J*=6.0Hz, 3H), 1.28 (s, 6H), 1.54–1.63 (m, 2H), 2.62 (t, *J*=9.0Hz, 2H), 2.95 (t, *J*=6.0Hz, 2H), 4.05 (t, *J*=6.0Hz, 2H), 7.19–7.41 (m, 5H). MS(*m/z*):235(M+1$^+$, 19.65), 104(100.00), 91(60.41), 43(56.71), 41(43.53), 105(39.73), 133(21.01), 150(17.76).

Compound **5**: ^{1}H NMR (400MHz, $CDCl_3$): δ 7.29–7.17 (m, 5H, Ph-H), 4.05 (t, *J*=6.7Hz, 2H, O–CH_2), 2.95 (t, *J*=7.8Hz, 2H, Ph–CH_2), 2.62 (dd, *J*=7.8Hz, 2H, CO–CH_2), 1.60–1.57 (m, 2H, Me–CH_2), 1.28 (s, 8H, 4CH_2), 0.88 (t, *J*=6.8Hz, 3H, CH_3). MS(*m/z*):249(M+1$^+$, 2.76), 104(100.00), 57(52.27), 91(49.91), 41(31.76), 150(31.47), 43(27.99), 55(13.04).

Compound **6**: ^{1}H NMR (400MHz, $CDCl_3$): δ 7.30–7.17 (m, 5H, Ph-5), 4.08–4.04 (m, 2H, O–CH_2), 2.97–2.93 (m, 2H, Ph–CH_2), 2.64–2.60 (m, 2H, CO–CH_2), 1.59 (s, 2H, Me–CH_2), 1.28 (s, 10H, 5CH_2), 0.88 (t, *J*=5. 6Hz, 3H, CH_3). Lit[20]: ^{1}H NMR (500MHz, $CDCl_3$): δ 0.86–0.89 (t, 3H), 1.27 (s, 10H), 1.57–1.59 (t, 2H), 2.60–2.63 (t, 2H), 2.93–2.96 (t, 2H), 4.03–4.06 (t, 2H), 7.17–7.29 (m, 5H). MS(*m/z*):263(M+1$^+$, 2.75), 104(100.00), 91(47.44), 150(35.86), 57(35.03), 43(33.86), 105(29.60), 41(26.86), 71(22.68).

Compound **7**: ^{1}H NMR (400MHz, $CDCl_3$): δ 7.30–7.15 (m, 10H, Ph–H), 4.28 (t, *J*=7.1Hz, 2H, O–CH_2), 2.90 (dd, *J*=7.2Hz, 4H, Ph–CH_2), 2.60 (t, *J*=7.8Hz, 2H, CO–CH_2). Lit[20]: ^{1}H NMR (500MHz, $CDCl_3$): δ 2.56–2.59 (m, 2H), 2.84–2.89 (m, 4H), 4.21–4.24 (t, 2H), 7.14–7.29 (m, 10H). MS(*m/z*):255(M+1$^+$, 47.00), 104(100.00), 105(74.13), 91(54.74), 77(22.76), 65(21.55), 103(16.45), 57(13.75).

Compound **8**: ^{1}H NMR (400MHz, $CDCl_3$): δ 7.29–7.17 (m, 5H, Ph–H), 4.89 (dd, *J*=6.1Hz, 1H, O–CH), 2.94 (t, *J*=7.7Hz, 2H, Ph–CH_2), 2.60 (t, *J*=7.7Hz, 2H, CO–CH_2), 1.48 (m, 2H, Me–CH_2), 1.25 (s, 8H, 4CH_2), 1.16 (d, *J*=6.15Hz, 3H, CH–CH_3), 0.88 (t, *J*=6.2Hz, 3H, CH_2–CH_3). Lit[21]: ^{1}H NMR (200MHz, $CDCl_3$): δ 7.33–7.19 (5H, m), 4.89 (1H, m), 2.95 (2H, t, *J* 7.4Hz), 2.61 (2H, t, *J* 7.4Hz), 1.48 (2H, m), 1.25 (8H, br, s), 1.17 (3H, d, *J* 6.4Hz), 0.88 (3H, t, J 6.4Hz). MS(*m/z*):262(M$^+$, 2.50), 104(100.00), 150(59.20), 103(38.75), 91(33.72), 41(18.31), 133(15.01), 151(13.97), 77(13.13).

Compound **9**: ^{1}H NMR (400MHz, $CDCl_3$): δ 8.06–7.41 (m, 5H, Ph–H), 4.31 (t, *J*=6.7Hz, 2H, O–CH_2), 1.76 (t, *J*=7.4Hz, 2H, Me–CH_2), 1.44–1.28 (m, 8H, 4CH_2), 0.89 (t, *J*=6.9Hz, 3H, CH_3). Lit[22]: ^{1}HNMR($CDCl_3$): δ 0.75–3.0 (m, 13H), 4.25 (t, 2H), 7.1–8.05 (m, 5H). MS(*m/z*):221(M+1$^+$, 43.49), 105(100.00), 123(29.73), 41(20.34), 77(14.73), 43(13.44), 57(12.55), 51(8.96).

Compound **10**: ^{1}H NMR (400MHz, $CDCl_3$): δ 8.06–7.41 (m, 5H, Ph–H), 4.31 (t, *J*=6.7Hz, 2H, O–CH_2), 1.75 (dd, *J*=7.05Hz, 2H, Me–CH_2), 1.73–1.28 (m, 10H, 5CH_2), 0.88 (t, *J*=6.9Hz, 3H, CH_3). Lit[20]: ^{1}H NMR (500MHz, $CDCl_3$): δ 0.87–0.89 (t, 2H), 1.28–1.35 (m, 8H), 1.41–1.45 (m, 2H), 1.73–1.79 (m, 2H), 4.30–4.32 (t, 2H), 7.41–8.05 (m, 5H). MS(*m/z*):235(M+1$^+$, 39.44), 105(100.00), 77(58.57), 41(55.17), 123(49.13), 43(35.10), 51(31.12), 55(28.75).

Compound **11**: ^{1}H NMR (400MHz, $CDCl_3$): δ 8.02–7.20 (m, 10H, Ph–H), 4.51 (t, *J*=7.0Hz, 2H, O–CH_2), 3.06 (t, *J*=7.1Hz, 2H, Ph-CH_2). Lit[23]: ^{1}H NMR (CCl_4): δ 7.94(2H), 7.30(3H), 7.15(5H), 4.41(2H), 2.96(2H). MS(*m/z*):227(M+1$^+$, 1.55), 104(100.00), 105(99.35), 77(12.07), 91(11.57), 106(8.56), 51(7.01), 65(6.09), 209(4.89).

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