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A rapid and efficient method for synthesis of new 3-arylideneisobenzofuran-1(3H)-one derivatives catalyzed by acetic anhydride under solvent-free and microwave conditions

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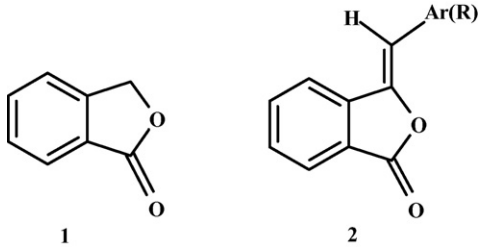
Abstract

In this study we have described the synthesis of new 3-arylidene isobenzofuran-1(3H)-one derivatives. Condensation reaction of phthalic anhydride and quinoline derivatives under solvent-free condition and microwave irradiation in the presence of acetic anhydride as catalyst in good excellent yield is reported.

Keywords: Catalyst; Synthesis; Microwave; Solvent-free; Quinoline

1. Introduction

Compounds containing the phthalide[isobenzofuran-1(3H)-one] **1** structure have drawn considerable interest. 3-Arylidene or 3-alkylidene phthalides **2** have been used extensively as intermediates for the synthesis of various drugs [1–4] and naturally occurring compounds.



1 2

The biological activities of 3-arylidene or 3-alkylidene phthalides as antispasmodic, herbicidal and insecticidal agents [5], as pesticides [6], cytotoxic agents [7] and as prostaglandin F_2a inhibitors [8] by different investigators.

Over a period of more than a 100 years, a number of methods have been developed for the synthesis of 3-alkylidene or 3-arylidene phthalides and phthalide containing natural products. These can be classified in the following categories: (i) a high temperature method [9,10], originally developed by Gabriel which involved the reaction of phthalic anhydride with acetic anhydride or an arylacetic acid at 230–250 °C; (ii) base-catalyzed condensation [11–13] of phthalides with aldehydes; (iii) a Wittig-Horner-type condensation of aromatic aldehydes and phthalide phosphonates [14,15]; (iv) condensation of an *o*-halobenzoic acid with Cu(I) acetylides (Castro reaction) [16].

Various modifications of the above reactions have also been described [17–20]. The synthesis of 3-alkylidene phthalides from photochemical rearrangements of substituted inden-1,3-diones and electrochemical reduction of phthaloyl chloride has been reported [21,22]. Also, the other works for preparation of these compounds have been reported through iodolactonization of methyl 2-ynylbenzoates [23], palladium [24] and solid base [25] catalyzed reactions, photo catalyzed reaction by titanium dioxide [26] and comparative intramolecular dehydrative lactonization of 4-oxo carboxylic acids [27].

Some of the above mentioned methods including long reaction times, low yields, difficult operating conditions and tedious work-up. We were prompted to develop a general and efficient

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method for the synthesis of 3-arylidene phthalides starting from phthalic anhydride and quinoline derivatives under solvent-free conditions and microwave irradiation in the presence of acetic anhydride as catalyst.

2. Experimental

2.1. Materials

Chemicals were purchased from the Merck Chemical Company in high purity. All of the materials were of commercial reagent grade. Phthalic anhydrides and quinoline compounds were purified by standard procedures.

2.2. Apparatus

Melting points were determined in open capillaries using an Electrothermal Mk3 apparatus. Infrared (IR) spectra were recorded using a Perkin-Elmer FT-IR 550 spectrometer. ^{1}H NMR and ^{13}C NMR spectra were recorded on a Bruker DRX-500 spectrometer for sample as indicated with tetramethylsilane as internal reference. Uv spectra were recorded on a Hitachi 200-20 spectrometer using spectrophotometeric grade chloroform (Baker). Mass spectra were recorded on a Finnigan MAT 44S, with an ionization voltage of 70 eV. The element analyses (C.H.N.) were obtained from a Carlo ERBA Model EA 1108 analyzer carried out on Perkin-Elmer 240c analyzer. The microwave oven used was a commercial household microwave oven (Moulinex FM1935G, frequency: 2450 MHz).

2.3. General procedure

2.3.1. General procedure for the synthesis of phthalides under thermal conditions

A mixture of quinoline (0.9 ml, 6.66 mmol), phthalic anhydride (1 g, 6.75 mmol) and acetic anhydride (1.5 ml) was stirred well in a beaker at room temperature. The mixture was heated at 130–140 °C. After 2–4 min the reaction was completed. Then was added distilled water and $NaHCO_3$ and were stirred for 20 min, the mixture was filtered and extracted with petroleum ether (3 × 10 ml). Evaporation of the solvent was afforded the product. The crude product was recrystallized from chloroform and the pure product, 1-(2-quinolyl)-methylidene-1(3H)-isobenzofuranone was obtained as crystalline in 85% yield (Table 2).

2.3.2. General procedure for the synthesis of phthalides under microwave irradiation

A mixture of quinoline (0.9 ml, 6.66 mmol), phthalic anhydride (1 g, 6.75 mmol) and acetic anhydride (1.5 ml) was stirred well in a beaker at room temperature. Then the mixture was irradiated with microwave oven (100 W). After 20–150 s, the reaction was completed. Then was added distilled water and $NaHCO_3$ and were stirred for 20 min, the mixture was filtered and extracted with petroleum ether (3 × 10 ml). Evaporation of the solvent was afforded the product. The corde product was recrystallized from chloroform and the pure 1-(2-quinolyl)-methylidene-1(3H)-isobenzofuranone was obtained as crystalline in 90% yield (Table 2).

2.3.2.1. 3-[(E)-1-(2-quinolyl)methylidene]-1(3H)-isobenzofuranone (aa′). mp 152–155 °C. IR (KBr): υ = 1780, 1680, 1080, 1425–1600 cm^{-1}. ^{1}H NMR (500 MHz, $CDCl_3$): δ = 6.99 (s, 1H, vinylic H), 7.5–8.3 (m, 10H, Ar–H). ^{13}C NMR (125 MHz, $CDCl_3$): δ = 165.2, 154.1, 152.2, 150.5, 145.7, 136.5, 136.1, 134.5, 131.7, 130.9, 129.5, 127.4, 126.4, 125.3, 122.9, 121.9, 118.8, 107.2. Mass (*m*/*z*): 274 (*M* + 1, 12), 273 ($M^{\bullet+}$, 100), 217 (70), 216 (48), 204 (27), 140 (32), 128 (36), 76 (43). Uv ($CDCl_3$): λ_{max} = 390, 373 nm. Anal. Calcd for $C_{18}H_{11}O_2N$: C, 79.10; H, 4.05; N, 5.58. Found: C, 79.25; H, 4.01; N, 5.49.

2.3.2.2. 4,5,6,7-Tetrachloro-3-[(E)-1-(2-quinolyl) methylidene]-1(3H)-isobenzofuranone (ab′). mp 286 °C. IR (KBr): υ = 1782, 1630, 1216, 1400–1590 cm^{-1}. ^{1}H NMR (500 MHz, $CDCl_3$): δ = 7.0 (s, 1H, vinylic H), 7.55–8.48 (m, 6H, Ar–H). ^{13}C NMR (125 MHz, $CDCl_3$): δ = 167.2, 154.8, 153.4, 150.1, 144.7, 140.0, 139.2, 136.1, 134.2, 131.9, 130.1, 128.4, 128.1, 127.6, 127.5, 126.8, 118.5, 108.3. Mass (*m*/*z*): 413 (*M* + 2, 33), 411 ($M^{\bullet+}$, 74), 376 (83), 374 (87), 355 (95), 318 (23), 238 (43), 248 (27), 212 (45), 173 (35), 140 (100), 114 (46), 75 (35). Uv ($CDCl_3$): λ_{max} = 350 nm. Anal. Calcd for $C_{18}H_7Cl_4O_2N$: C, 52.59; H, 1.71; N, 8.80. Found: C, 52.20; H, 1.78; N, 8.69.

2.3.2.3. 7-Nitro-3-[(E)-1-(2-quinolyl)methylidene]-1(3H)-isobenzofuranone (ac′). mp 286 °C. IR (KBr): υ = 1782, 1630, 1216, 1400–1590 cm^{-1}. ^{1}H NMR (500 MHz, $CDCl_3$): δ = 7.0 (s, 1H, vinylic H), 7.55–8.48 (m, 9H, Ar–H). ^{13}C NMR (125 MHz, $CDCl_3$): δ = 168.4, 155.4, 149.8, 149.5, 144.6, 144.1, 136.9, 135.8, 134.7, 132.4, 129.7, 128.4, 126.4, 125.0, 122.2, 120.9, 118.5, 106.7. Mass (*m*/*z*): 319 (*M* + 1, 13), 318 ($M^{\bullet+}$, 50), 273 (14), 214 (22), 161 (52), 149 (28), 103 (30), 89 (60), 75 (100). Uv ($CDCl_3$): λ_{max} = 310, 190, 177 nm. Anal. Calcd for $C_{18}H_{10}O_4N_2$: C, 67.92; H, 3.16; N, 8.80. Found: C, 67.61; H, 3.05; N, 8.68.

2.3.2.4. 6-Nitro-3-[(E)-1-(2-quinolyl)methylidene]-1(3H)-isobenzofuranone (ad′). mp 227–228 °C. IR (KBr): υ = 1792, 1615, 1330, 1535–1640 cm^{-1}. ^{1}H NMR (500 MHz, $CDCl_3$): δ = 7.17 (s, 1H, vinylic H), 7.65–8.77 (m, 9H, Ar–H). ^{13}C NMR (125 MHz, $CDCl_3$): δ = 162.4, 154.2, 152.8, 151.2, 150.8, 149.7, 136.9, 135.0, 131.7, 130.6, 129.4, 128.6, 127.1, 125.8, 122.04, 119.1, 106.9. Mass (*m*/*z*): 319 (*M* + 1, 15), 318 ($M^{\bullet+}$, 60), 273 (17), 214 (27), 161 (44), 149 (41), 103 (37), 89 (65), 75 (100). Uv ($CDCl_3$): λ_{max} = 375, 361 nm. Anal. Calcd for $C_{18}H_{10}O_4N_2$: C, 67.92; H, 3.16; N, 8.80. Found: C, 67.52; H, 3.11; N, 8.64.

2.3.2.5. 3-[(E)-1-(4-quinolyl)methylidene]-l(3H)-isobenzofuranone (ba′). mp 186 °C, IR (KBr): υ = 1785, 1585, 1277, 1400–1600 cm^{-1}. ^{1}H NMR (500 MHz, $CDCl_3$): δ = 7.7 (s, 1H, vinylic H), 7.21–8.97 (m, 10H, Ar–H). ^{13}C

NMR(125 MHz, $CDCl_3$): δ = 170.7, 154.6, 153.9, 148.2, 146.3, 138.9, 136.7, 133.9, 132.7, 132.5, 129.8, 128.7, 127.8, 126.4, 125.7, 121.6, 119.2, 117.1. Mass (*m/z*): 274 (*M* + 1, 10), 273 ($M^{\bullet+}$, 100), 217 (75), 216 (140), 204 (35), 140 (25), 128 (30), 76 (25). Uv ($CDCl_3$): λ_{max} = 371 nm. Anal. Calcd for $C_{18}H_{11}O_2N$: C, 79.10; H, 4.05; N, 5.58. Found: C, 79.01; H, 4.01; N, 5.41.

2.3.2.6. 4,5,6,7-Tetrachloro-3-[(E)-1-(4-quinolyl)methylidene]-1(3H)-isobenzofuranone (bb′). mp 230 °C. IR (KBr): υ = 1784, 700, 1230, 1390–1610 cm^{-1}. ^1H NMR (500 MHz, $CDCl_3$): δ = 7.48 (s, 1H, vinylic H), 7.68–8.95 (m, 6H, Ar–H). ^{13}C NMR (125 MHz, $CDCl_3$): δ = 166.9, 154.0, 151.2, 147.2, 143.7, 141.2, 140.1, 138.2, 134.5, 132.4, 130.4, 130.1, 129.7, 129.3, 128.7, 127.8, 119.4, 112.3. Mass (*m/z*): 413 (*M* + 2, 33), 411 ($M^{\bullet+}$, 45), 374 (25), 318 (15), 284 (34), 242 (98), 214 (100), 179 (46), 140 (24), 107 (82), 95 (41), 71 (36). Uv ($CDCl_3$): λ_{max} = 335 nm. Anal. Calcd for $C_{18}H_7Cl_4O_2N$: C, 52.59; H, 1.71; N, 8.80. Found: C, 52.45; H, 1.61; N, 8.66.

2.3.2.7. 7-Nitro-3-[(E)-1-(4-quinolyl)methylidene]-1(3H)-isobenzofuranone (bc′). mp 235 °C. IR (KBr): υ = 1784, 1608, 1338, 1480–1540 cm^{-1}. ^1H NMR (500 MHz, $CDCl_3$): δ = 7.59 (s, 1H, vinylic H), 7.7–8.8 (m, 9H, Ar–H). ^{13}C NMR (125 MHz, $CDCl_3$): δ = 166.7, 156.4, 153.8, 149.6, 145.3, 140.2, 137.6, 135.9, 134.1, 132.2, 129.7, 128.9, 128.0, 123.9, 122.1, 118.7, 116.0. Mass (*m/z*): 319 (*M* + 1, 13), 318 ($M^{\bullet+}$, 62), 273 (11), 214 (17), 161 (48), 149 (28), 103 (39), 89 (65), 75 (100). Uv ($CDCl_3$): λ_{max} = 328, 210 nm. Anal. Calcd for $C_{18}H_{10}O_4N_2$: C, 67.92; H, 3.16; N, 8.80. Found: C, 67.55; H, 3.17; N, 8.75.

2.3.2.8. 6-Nitro-3-[(E)-1-(4-quinolyl)methylidene]-1(3H)-isobenzofuranone (bd′). mp 202 °C. IR (KBr): υ = 1793, 1615, 1338, 1530–1625 cm^{-1}. ^1H NMR (500 MHz, $CDCl_3$): δ = 7.37 (s, 1H, vinylic H), 7.74–8.95 (m, 9H, Ar–H). ^{13}C NMR (125 MHz, $CDCl_3$): δ = 166.5, 155.9, 153.4, 153.2, 149.8, 145.0, 139.2, 133.6, 131.5, 130.9, 130.4, 129.7, 129.1, 128.6, 127.2, 120.0, 118.5, 116.6. Mass (*m/z*): 319 (*M* + 1, 15), 318 ($M^{\bullet+}$, 55), 273 (17), 214 (27), 161 (48), 149 (41), 103 (39), 89 (65), 75 (100). Uv ($CDCl_3$): λ_{max} = 320 nm. Anal. Calcd for $C_{18}H_{10}O_4N_2$: C, 67.92; H, 3.16; N, 8.80. Found: C, 67.66; H, 3.20; N, 8.52.

2.3.2.9. 3-[(E)-1-(3-methyl-2-quinolyl)methylidene]-1(3H)-isobenzofuranone (ca′). mp 180 °C. IR (KBr): υ = 1772, 1690, 1252, 1490–1590 cm^{-1}. ^1H NMR (500 MHz, $CDCl_3$): δ = 2.96 (s, 3H, CH_3), 6.94 (s, 1H, vinylic H), 7.5–8.3 (m, 9H, Ar–H). ^{13}C NMR (125 MHz, $CDCl_3$): δ = 164.2, 155.5, 152.9, 149.8, 142.1, 139.7, 139.2, 134.7, 132.4, 130.9, 130.2, 129.7, 129.0, 128.6, 128.1, 126.7, 123.4, 105.9, 17.6. Mass (*m/z*): 287 ($M^{\bullet+}$, 44), 270 (23), 243 (35), 115 (28), 104 (60), 76 (100), 50 (39). Uv ($CDCl_3$): λ_{max} = 340 nm. Anal. Calcd for $C_{19}H_{14}O_2N$: C, 79.14; H, 4.89; N, 4.85. Found: C, 78.93; H, 4.78; N, 4.91.

2.3.2.10. 4,5,6,7-Tetrachloro-3-[(E)-1-(3-methyl-2-quinolyl)methylidene]-1(3H)-isobenzofuranone (cb′). mp 214–215 °C. IR (KBr): υ = 1785, 1645, 1285, 1500–1600 cm^{-1}. ^1H NMR (500 MHz, $CDCl_3$): δ = 2.59 (s, 3H, CH_3), 7.56 (s, 1H, vinylic H), 7.71–8.1 (m, 5H, Ar–H). ^{13}C NMR (125 MHz, $CDCl_3$): δ = 163.9, 154.3, 152.3, 148.5, 145.9, 137.2, 134.5, 132.8, 130.9, 128.4, 128.0, 127.1, 126.7, 124.5, 124.1, 122.7, 121.1, 106.1, 16.9. Mass (*m/z*): 428 (*M* + 2, 30), 426 ($M^{\bullet+}$,35), 389 (30), 318 (15), 284 (21), 229 (100), 179 (40), 122 (40), 95 (42), 107 (25). Uv ($CDCl_3$): λ_{max} = 360 nm. Anal. Calcd for $C_{19}H_{10}Cl_4O_2N$: C, 53.55; H, 2.36; N, 3.28. Found: C, 52.90; H, 2.30; N, 3.17.

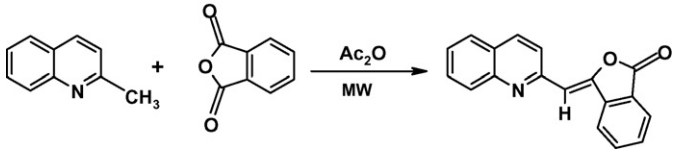
2.3.2.11. 7-Nitro-3-[(E)-1-(3-methyl-2-quinolyl)methylidene]-1(3H)-isobenzofuranone (cc′). mp 164 °C. IR (KBr): υ = 1777, 1525, 1335, 1535 cm^{-1}. ^1H NMR (500 MHz, $CDCl_3$): δ = 2.60 (s, 3H, CH_3), 7.53 (s, 1H, vinylic H), 7.62–8.54 (m, 8H, Ar–H). ^{13}C NMR (125 MHz, $CDCl_3$): δ = 166.2, 154.9, 149.5, 146.7, 143.4, 143.0, 136.4, 133.8, 131.9, 131.4, 128.9, 128.1, 127.0, 126.1, 125.1, 122.6, 105.0, 16.8. Mass (*m/z*): 332 ($M^{\bullet+}$, 35), 315 (25), 286 (33), 228 (47), 215 (20), 142 (62), 115 (32), 89 (54), 75 (100). Uv ($CDCl_3$): λ_{max} = 338 nm. Anal. Calcd for $C_{19}H_{13}O_4N_2$: C, 68.46; H, 3.93; N, 8.40. Found: C, 67.59; H, 3.86; N, 8.53.

2.3.2.12. 6-Nitro-3-[(E)-1-(3-methyl-2-quinolyl)methylidene]-1(3H)-isobenzofuranone (cd′). mp 108 °C. IR (KBr): υ = 1782, 1530, 1338, 1480–1600 cm^{-1}. ^1H NMR (500 MHz, $CDCl_3$): δ = 2.66 (s, 3H, CH_3), 7.23 (s, 1H, vinylic H), 7.62–8.60 (m, 8H, Ar–H). ^{13}C NMR (125 MHz, $CDCl_3$): δ = 162.1, 155.2, 152.4, 149.7, 148.6, 147.9, 134.5, 132.1, 131.8, 129.8, 129.1, 128.6, 128.0, 126.4, 124.8, 124.1, 104.5, 16.6. Mass (*m/z*): 332 ($M^{\bullet+}$, 30), 315 (25), 286 (30), 228 (55), 215 (20), 142 (62), 115 (32), 89 (54), 75 (100). Uv ($CDCl_3$): λ_{max} = 324 nm. Anal. Calcd for $C_{19}H_{13}O_4N_2$: C, 68.46; H, 3.93; N, 8.40. Found: C, 68.01; H, 3.84; N, 8.34.

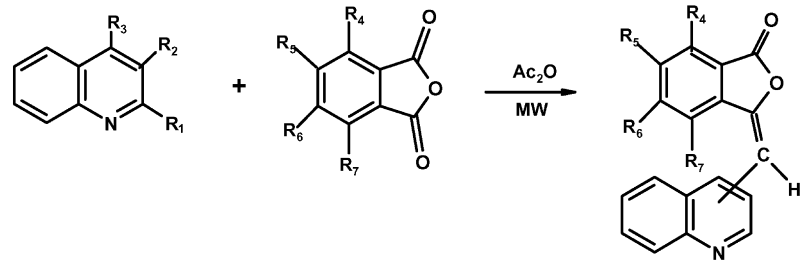
3. Results and discussion

In this research, in order to choose the appropriate catalyst some of the common desiccants such as calcium chloride (anhydrous), phosphorous pentoxide, sodium sulfate (anhydrous), acetic anhydride, calcium carbonate (anhydrous) and silica gel were selected. Then, a comparative study was carried out by using 2-methyl-quinoline and phthalic anhydride as starting materials in the presence of these desiccants as catalyst (Scheme 1).

The corresponding results are summarized in Table 1. The samples were heated at 130–140 °C in the presence of catalysts. The results in Table 1 were indicated that acetic anhydride was the best catalyst and consequently this catalyst was selected for subsequent experiments. Because, the acetic anhydride is including both quantitatively and qualitatively advantages such



Scheme 1.



I II III

Ia) R_1=CH_3, R_2 =R_3 =H

Ib) R_1=R_2 =H, R_3 =CH_3

Ic) R_1=R_2 =CH_3, R_3 =H

IIa′) R_4 = R_5 = R_6 = R_7 = H

IIb′) R_4 = R_5 = R_6 = R_7 =Cl

IIc′) R_4 = R_5 = R_6 = H, R_7 =NO_2

IId′) R_4 = R_5 = R_7 = H, R_6 = NO_2

Scheme 2.

Table 1
3-Arylidene phthalides formation in the presence of various catalysts

Run	Catalyst	Time (min)	Yield (%)
1	$CaCO_3$	10	0
2	$CaCl_2$	6	10
3	P_2O_5	5	15
4	Silica gel	9	25
5	Na_2SO_4	8	30
6	Ac_2O	4	85

as; availability, cheapness, ability of coordination with quinoline nitrogen in reaction pathway. It is also the most useful for the progress of the reaction than the other used catalyst.

Then, a variety of 3-arylidene phthalides were prepared from quinoline and phthalic anhydride derivatives under (i) conventional and solvent-free condition and (ii) microwave irradiation, in the presence of acetic anhydride (Scheme 2). The results are indicated in Table 2. As shown in this table, in these reactions, the phthalide derivatives were yielded in high yields and short reaction times under mild conditions at room temperature.

The structure of the 3-arylidene phthalides products have confirmed by their spectroscopic data. In IR spectra, the presence of signal at 1775–1795 cm^{-1} due to C=O related to the γ-lactone ring, whereas a vinylic hydrogen could be seen at δ 6.9–7.3 in the ^{1}H NMR spectra.

The stereochemistry of the isomeric products was based on the chemical shifts of the vinylic protons. In the *Z*-isomers, the vinylic proton chemical shift being at the somewhat higher field compared with that of the E-isomers [9,19,28,29,30] where the vinylic proton was deshielded due to the oxygen atom of lactone. The quinoline ring is not effective in appearance of the vinylic proton chemical shift. Thus, on the basis of the chemical shift, the obtained compound would be the E-isomer, by this method.

4. Conclusion

In this research, we have described a very convenient and general method for the synthesis of 3-arylideneisobenzofuran-1-(3H)-ones (phthalide derivatives). This method is characterized by (i) easy availability of inexpensive starting materials, (ii) use

Table 2
The reaction of quinoline derivatives with phthalic anhydride derivatives in thermal condition and microwave irradiation

Entry	Quinoline (I)	Anhydride (II)	Product (III)	Thermal condition		Microwave irradiation	
				Time (s)	Yield[a] (%)	Time (s)	Yield[a] (%)
1	a	a′	aa′	180	90	90	95
2	a	b′	ab′	80	75	20	85
3	a	c′	ac′	120	85	60	85
4	a	d′	ad′	240	80	150	80
5	b	a′	ba′	210	75	120	80
6	b	b′	bb′	90	60	50	75
7	b	c′	bc′	120	80	75	80
8	b	d′	bd′	240	75	160	80
9	c	a′	ca′	180	65	120	70
10	c	b′	cb′	120	80	120	80
11	c	c′	cc′	150	85	60	85
12	c	d′	cd′	180	90	150	90

[a] Isolated yields based on quinoline derivatives.

of non-toxic reagents, (iii) solvent-free condition and (iv) simple operational procedure (one step reaction).

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References

[1] P. Hrnciar, V. Kovalcik, Chem. Zvesti. 16 (96) (1962) 200;
P. Hrnciar, V. Kovalcik, Chem. Abstr. 59 (1963) 2731b.
[2] T.G. Sinay, R. Sysko, J. Eur. Pat. (1989) 314;
T.G. Sinay, R. Sysko, Chem. Abstr. 112 (1990) 77211h.
[3] I. Cerskus, R.B. Philip, Agents Actions 11 (1981) 281.
[4] K. Kubota, Y. Ogawa, K. Hosaka, M. Chin, Jpn, Kokai Tokkyo Koho, JP01, 50 (1990) 818;
K. Kubota, Y. Ogawa, K. Hosaka, M. Chin, Chem. Abstr. 112 (1990) 76923e.
[5] W.C. Ko, L.C. Lin, S.H. Lin, P.Y. Hwang, C.Y. Hsu, G.Y. Wang, C.W. Chang, Taiwan Yao Hsueh Tsa Chih, 35 (1983) 155;
W.C. Ko, L.C. Lin, S.H. Lin, P.Y. Hwang, C.Y. Hsu, G.Y. Wang, C.W. Chang, Chem. Abstr. 101 (1984) 48511y.
[6] M. Lacova, Czech. Pat. 257 (1986) 137;
M. Lacova, Chem. Abstr. 111 (1989) 115015m.
[7] J. Fuska, A. Fuskova, B. Proksa, Chem. Abstr. 106 (1987) 95582k.
[8] O. Yoshimitsu, H. Kunio, K. Kiyoshi, C. Masao, Jpn, Kokai Tokkyo Koho, JP04 77, 480 [92 77, 480] (1990);
O. Yoshimitsu, H. Kunio, K. Kiyoshi, C. Masao, Chem. Abstr. 117 (1992) 69721n.
[9] (a) S. Gabriel, Ber. Dtsch. Chem. Ges. 19 (1986) 838;
S. Gabriel, Ber. Dtsch. Chem. Ges. 26 (1893) 952;
(b) R. Weiss, Org. Synth. 2 (1943) 61;
(c) G. Berti, Gazz. Chim. Ital. 86 (1956) 656;
(d) Z.J. Vejdelek, O. Newmecek, V. Musil, A. Simek, Collect. Czech. Chem. Commun. 29 (1964) 776.
[10] J. Rigaudy, P. Derible, Bull. Soc. Chim. Fr. (1965) 3047.
[11] (a) R.L. Shriner, L.S. Keyser, J. Org. Chem. 5 (1940) 200;
(b) E.D. Bergmann, J. Org. Chem. 21 (1956) 461.
[12] (a) S.L. Shapiro, K. Geiger, L. Freedman, J. Org. Chem. 25 (1960) 1860;
(b) S.L. Shapiro, K. Geiger, L. Freedman, J. Org. Chem. 26 (1961) 3580.
[13] H. Zimmer, R.D. Barry, J. Org. Chem. 27 (1962) 3710.
[14] A. Yamaguchi, M. Okazaki, Nippon Kagaku Kaishi (1973) 110;
A. Yamaguchi, M. Okazaki, Chem. Abstr. 78 (1973) 84494.
[15] E. Napolitano, G. Spinelli, R. Fiaschi, A. Marsili, Synthesis (1985) 38.
[16] C.E. Castro, E.G. Gaughan, D.C. Owsley, J. Org. Chem. 31 (1966) 4071.
[17] P.A. Chopard, R.F. Hudson, R.G. Searle, Tetrahedron Lett. (1965) 2357.
[18] R.K. Howe, J. Org. Chem. 38 (1973) 4164.
[19] C.F. Ingham, R.A. Massy-Westropp, G.D. Reynolds, W.D. Thorpe, Aust. J. Chem. 28 (1975) 2499.
[20] (a) R.S. Mali, S.R. Patil, B.K. Kulkarni, S.N. Yeola, Ind. J. Chem., Sect. B 29 (1990) 319;
(b) R.S. Mali, S.R. Patil, Synth. Commun. 20 (1990) 167;
(c) R.S. Mali, P.G. Jagtap, J. Chem. Res. (s) (1993) 184.
[21] P. Hrnciar, A. Gaplovsky, V. Drgoncova, J. Donovalova, J. Chem. Pap. 40 (1986) 649;
P. Hrnciar, A. Gaplovsky, V. Drgoncova, J. Donovalova, Chem. Abstr. 106 (1987) 129037d.
[22] A. Guirado, F. Barba, M.B. Hursthouse, A. Martinez, A. Arcas, Tetrahedron Lett. 27 (1986) 4063.
[23] R. Rossi, A. Carpita, F. Bellina, P. Stabile, L. Mannia, Tetrahedron 59 (2003) 2067.
[24] F. Coelho, D. Veronese, C.H. Pavam, I.P. Vanderlei, R. Buffon, Tetrahedron 62 (2006) 4563.
[25] T. Seki, H. Tachikaw, T. Yamada, H. Hattori, J. Catal. 217 (2003) 117.
[26] M. Muneer, D. Bahnemann, M. Qamar, M.A. Tariq, M. Faisal, Appl. Catal. A: Gen. 289 (2005) 224.
[27] Taxus Research Laboratory, Vasvavi, P. U. 61, H-4440, T. Hungary, Arkivoc, 174 (2006) 174.
[28] N.G. Kundu, M. Pal, B. Nandi, J. Chem. Soc., Perkin Trans. 1 (1998) 561.
[29] R. Mukhopadhyay, N.G. Kundu, Tetrahedron 57 (2001) 9475.
[30] (a) M. Kapoor, S.N. Dhawan, S. Mor, S. Bhatia, S. Gupta, M.S. Hundal, Tetrahedron 59 (2003) 5027;
(b) K. Young Lee, J. Mikim, Synlett 3 (2003) 357.