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MODIFIED COUMARINS. I. SYNTHESIS OF 5-PHENYL-7H-FURO[2,3-g]CHROMEN-7-ONES AND 9-PHENYL-7H-FURO-[2,3-f]CHROMEN-7-ONES

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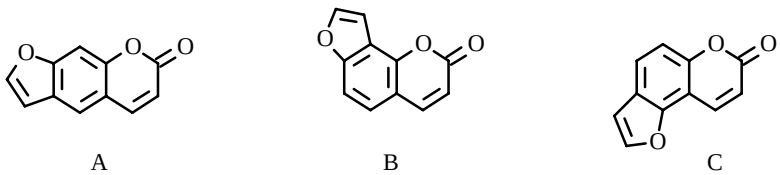
5-Phenyl-7H-furo[2,3-g]chromen-7-ones and 9-phenyl-7H-furo-[2,3-f]chromen-7-ones, new analogs of psoralen and allopsoralen, are synthesized from 7-hydroxy- and 5-hydroxy-4-phenylcoumarins.

Key words: 5-phenyl-7H-furo[2,3-g]chromen-7-one, 9-phenyl-7H-furo-[2,3-f]chromen-7-one, synthesis.

Furocoumarins are an important class of natural products that are isolated mainly from higher plants belonging to the families Rutaceae, Umbelliferae, Leguminosae, and Moraceae. These compounds are in most instances derivatives of the linear furocoumarin psoralen (A) or its angular isomers angelicin (B) and allopsoralen (C).



A B C

The ability to bind covalently DNA and other biological macromolecules under UV irradiation stimulates interest in the pharmacology of furocoumarins. Therefore, photosensitizing preparations of furocoumarins are widely used in the therapy of several skin diseases [1].

Derivatives of 4-phenylcoumarin (known as neoflavones) are widely distributed in the plant kingdom, especially among the families Dalbergia, Guttiferae, and Rubiaceae. More than 60 compounds based on the 4-phenylcoumarin framework have been isolated from natural materials. Both natural and synthetic 4-phenylcoumarins have a broad spectrum of biological activity. Neoflavones isolated from natural material exhibit antibactericidal and insecticidal properties [2, 3]. Synthetic derivatives of 4-phenylcoumarins possess vasodilating [4], analeptic [5], antiatherosclerotic [6], and antibacterial [7, 8] activities.

Thus, our goal was to modify the 4-phenylcoumarin structure by fusing a furan ring to it. This would possibly produce compounds with useful biological properties.

The starting 7-hydroxy-4-phenylcoumarin (**1**), 7-hydroxy-8-methyl-4-phenylcoumarin (**2**), and 5-hydroxy-7-methyl-4-phenylcoumarin (**3**) were obtained in high yields via Pechmann condensation of ethylbenzoylacetate and resorcinol, 2-methylresorcinol, and orcinol, respectively, in the presence of F_3CCO_2H [9]. We fused a furan ring to the 4-phenylcoumarin using the method of MacLeod et al. [10] based upon cyclization in alkaline medium of 1-(7-coumarinyloxy)acetone derivatives. The cyclization yields exclusively linear furocoumarins because the 6-position is strongly activated compared with the 8-position [10].

The Williamson reaction of 7-hydroxycoumarins **1** and **2** with α-bromoacetone or 3-chlorobutan-2-one in acetone in the presence of K_2CO_3 forms the corresponding substituted 1-(4-phenyl-7-coumarinyloxy)acetones (**4**-**7**). Using α-bromoacetophenone, α-bromo-4-chloroacetophenone, α-bromo-3,4-methylendioxyacetophenone, or α-bromopropiophenone in the alkylation reaction gives 2-(4-phenyl-7-coumarinyloxy)-1-phenyl-1-ethanone derivatives (**8**-**15**). Reaction of **1** and **2** with

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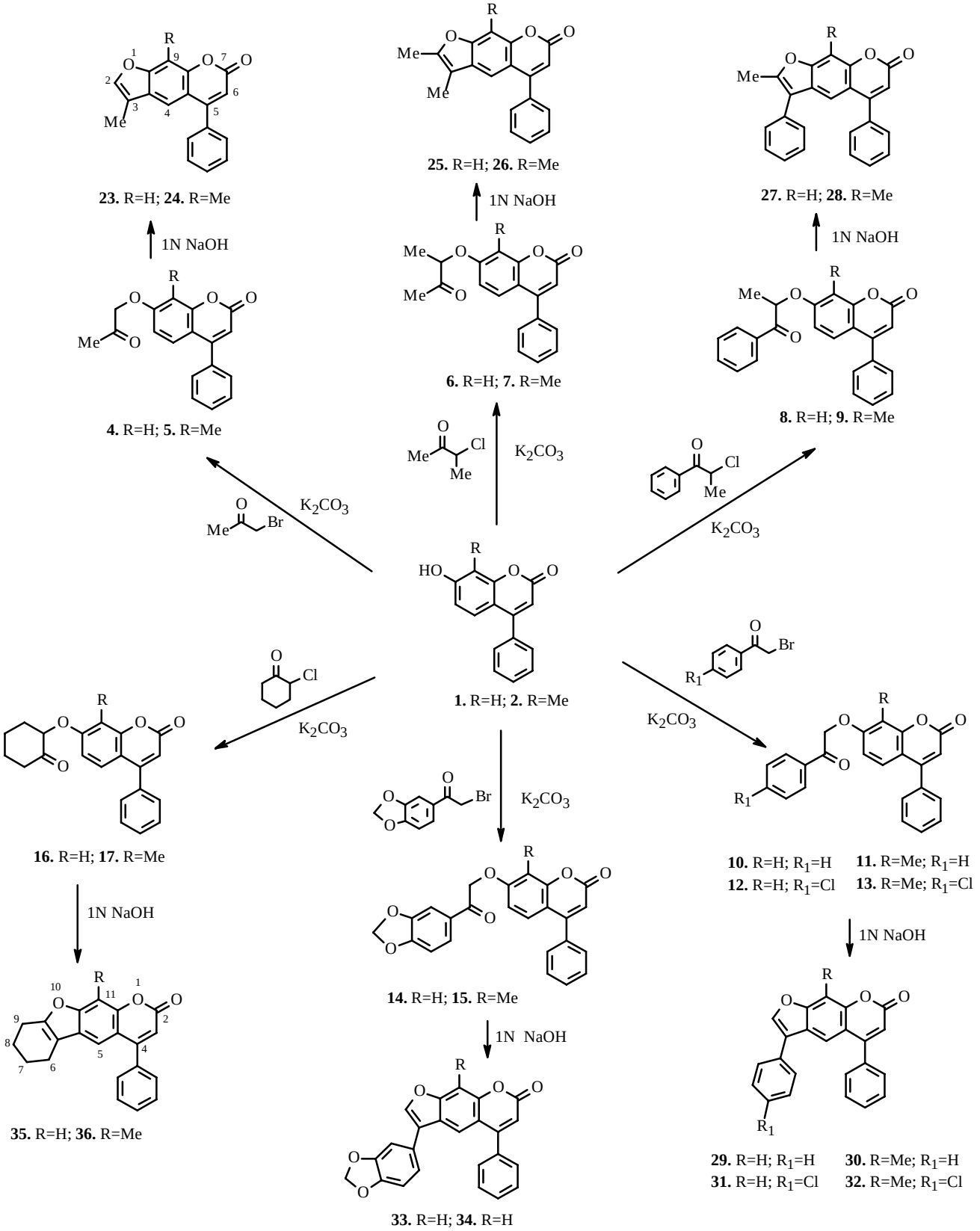
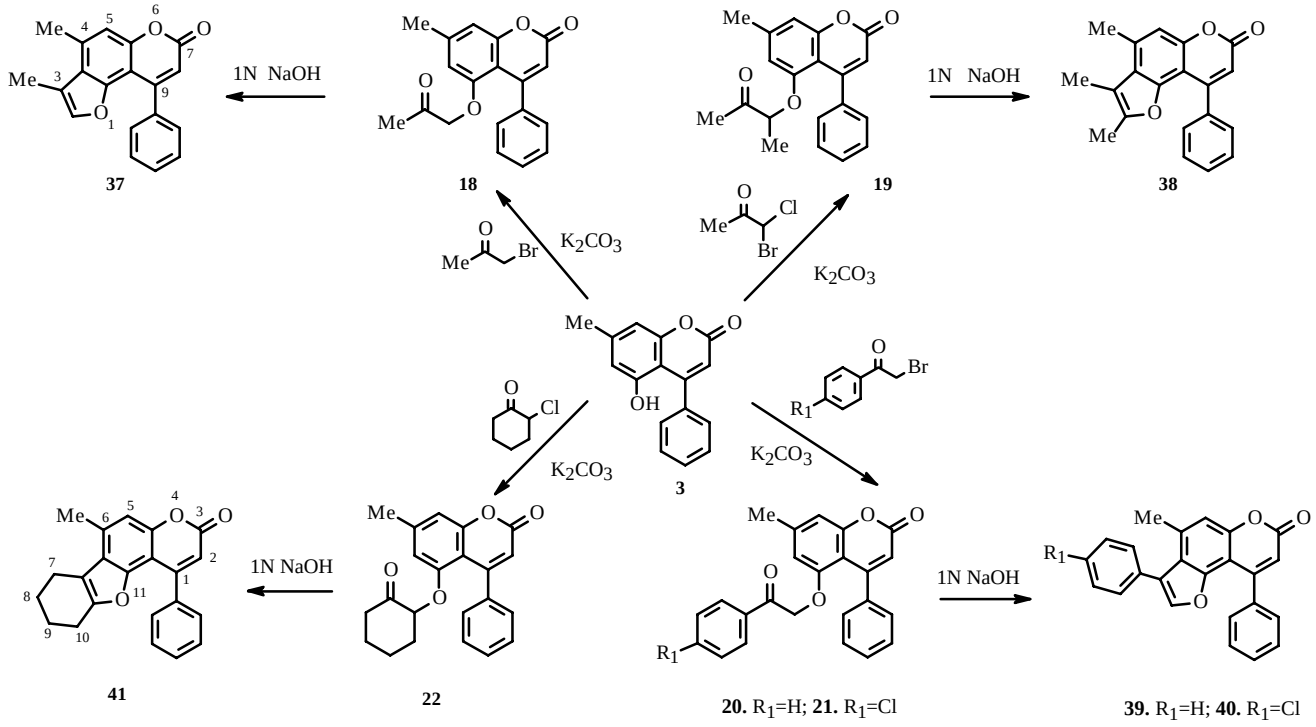
2-chlorocyclohexanone in DMF in the presence of K_2CO_3 gives 7-(2-oxocyclohexyloxy)-4-phenylcoumarins (**16** and **17**). The Williamson reaction of 5-hydroxycoumarin **3** with α-bromoacetone, 3-chlorobutan-2-one, α-bromoacetophenone, α-bromo-4-chloroacetophenone, and 2-chlorocyclohexanone forms ketones **18**-**22**.



Heating of ketones **4-22** with 1 N NaOH smoothly cyclizes them into the corresponding 5-phenyl-7H-furo[3,2-g]chromen-7-ones (**23-36**) (psoralen-type furocoumarins) and 9-phenyl-7H-furo[2,3-f]chromen-7-ones (**37-41**) (allopsoralen-type furocoumarins).



Fusion of the furan ring to the 6,7- (**23-36**) or 5,6-positions (**37-41**) of the coumarin core was confirmed by PMR spectroscopy. The PMR spectra of **23-36** exhibit a simplified splitting pattern in the aromatic region of coumarin owing to decoupling to H-6 of the coumarin ring. As a result, aromatic proton H-4 of furocoumarin appears as a singlet. An analogous situation is observed for **37-41** owing to decoupling of H-6 of the coumarin ring, causing H-5 of the furocoumarin to appear as a singlet. Furthermore, **23**, **24**, **29-34**, **37**, **39**, and **40**, which do not contain substituents in the 2-position, exhibit a 1H singlet for H-2 at 7.8-8.6 ppm. This is also characteristic of formation of a furocoumarin ring.

Thus, we prepared new psoralen and allopsoralen analogs based on 7-hydroxy- and 5-hydroxy-4-phenylcoumarins.

EXPERIMENTAL

The course of the reactions and the purity of the products were monitored using TLC on Silufol UV-254 plates and $CHCl_3$—CH_3OH (9:1) and (95:5). IR spectra were recorded on a Pye Unicam SP3-300 instrument in KBr pellets. PMR spectra were obtained on a Varian VXR-300 in DMSO-d_6 and deuteroacetone with TMS internal standard.

Hydroxycoumarins **1**, **2**, and **3** were prepared according to the literature [8].

7-(2-Oxopropoxy)-4-phenylcoumarin (4). A hot solution of **1** (2.38 g, 10 mmol) in absolute acetone (50 ml) was treated with freshly calcined potash (2.76 g, 20 mmol). The mixture was vigorously stirred, heated (50-56°C), and treated with α-bromoacetone (1.5 g, 11 mmol). The reaction mixture was heated and stirred vigorously for 1 h (completion of the reaction was determined by TLC). The reaction mixture was added to 1 N H_2SO_4 (300 ml). The resulting precipitate was filtered off and crystallized from propan-2-ol (75%). Yield 85%, mp 145°C, $C_{18}H_{14}O_4$. IR spectrum (KBr, cm^{-1}): 3040, 1712, 1625, 1598, 1560, 1435, 1366, 1334, 1240, 1132, 1061, 942, 875, 796, 766. PMR spectrum (300 MHz, deuteroacetone, δ, ppm): 2.25 (3H, s, CH_3CO), 4.95 (2H, s, $COCH_2O$), 6.16 (1H, s, H-3), 6.90 (1H, dd, J = 2.0 and 8.5 Hz, H-6), 6.95 (1H, d, J = 2.0 Hz, H-8), 7.41 (1H, d, J = 8.5 Hz, H-5), 7.56 (5H, m, Ph-4).

8-Methyl-7-(2-oxopropoxy)-4-phenylcoumarin (5) was prepared analogously to **4** using **2** (2.52 g, 10 mmol). Yield 92%, mp 159°C (75% propan-2-ol), $C_{19}H_{16}O_4$. IR spectrum (KBr, cm^{-1}): 1716, 1622, 1590, 1564, 1432, 1360, 1245, 1139, 1060, 945, 875, 785. PMR spectrum (300 MHz, deuteroacetone, δ, ppm): 2.25 (3H, s, CH_3CO), 2.36 (3H, s, CH_3-8), 4.91 (2H,

s, $COCH_2O$), 6.16 (1H, s, H-3), 6.85 (1H, d, J = 8.5 Hz, H-6), 7.25 (1H, d, J = 8.5 Hz, H-5), 7.54 (5H, m, Ph-4).

7-(1-Methyl-2-oxopropoxy)-4-phenylcoumarin (6) was prepared analogously to **4** using **1** (2.38 g, 10 mmol) and 3-chloro-2-butanone (1.11 ml, 11 mmol). The reaction mixture was heated for 4 h. Yield 82%, mp 123°C (60% propan-2-ol), $C_{19}H_{16}O_4$. IR spectrum (KBr, cm^{-1}): 3025, 1715, 1630, 1600, 1565, 1440, 1366, 1338, 1245, 1139, 1060, 942, 875, 780. PMR spectrum (300 MHz, deuteroacetone, δ, ppm): 1.56 (3H, d, α-CH_3), 2.24 (3H, s, CH_3CO), 5.08 (1H, q, COCHO), 6.17 (1H, s, H-3), 6.89 (1H, dd, J = 2.0 and 8.5 Hz, H-6), 6.95 (1H, d, J = 2.0 Hz, H-8), 7.42 (1H, d, J = 8.5 Hz, H-5), 7.58 (5H, m, Ph-4).

8-Methyl-7-(1-methyl-2-oxopropoxy)-4-phenylcoumarin (7) was prepared analogously to **4** using **2** (2.52 g, 10 mmol) and 3-chloro-2-butanone (1.11 ml, 11 mmol). The reaction mixture was heated for 4 h. Yield 86%, mp 151°C (75% propan-2-ol), $C_{20}H_{18}O_4$. IR spectrum (KBr, cm^{-1}): 3020, 1716, 1630, 1595, 1562, 1432, 1369, 1332, 1240, 1138, 1055, 940, 870, 786. PMR spectrum (300 MHz, deuteroacetone, δ, ppm): 1.55 (3H, d, α-CH_3), 2.22 (3H, s, CH_3CO), 2.37 (3H, s, CH_3-8), 5.00 (1H, q, COCHO), 6.17 (1H, s, H-3), 6.82 (1H, d, J = 8.5 Hz, H-6), 7.28 (1H, d, J = 8.5 Hz, H-5), 7.55 (5H, m, Ph-4).

7-(1-Methyl-2-oxo-2-phenylethoxy)-4-phenylcoumarin (8) was prepared analogously to **4** using **1** (2.38 g, 10 mmol) and 2-bromopropiophenone (1.64 ml, 11 mmol). The reaction mixture was heated for 2 h. Yield 81%, mp 109°C (propan-2-ol), $C_{24}H_{18}O_4$. IR spectrum (KBr, cm^{-1}): 3040, 1714, 1695, 1590, 1542, 1440, 1374, 1270, 1205, 1162, 1110, 990, 968, 835, 750. PMR spectrum (300 MHz, deuteroacetone, δ, ppm): 1.70 (3H, d, α-CH_3), 5.99 (1H, q, COCHO), 6.17 (1H, s, H-3), 6.89 (1H, dd, J = 2.0 and 8.5 Hz, H-6), 6.95 (1H, d, J = 2.0 Hz, H-8), 7.29 (1H, d, J = 8.5 Hz, H-5), 7.56 (5H, m, Ph-4), 7.60 (3H, m, H-3,4,5 PhCO), 8.15 (2H, m, H-2,6 PhCO).

8-Methyl-7-(1-methyl-2-oxo-2-phenylethoxy)-4-phenylcoumarin (9) was prepared analogously to **4** using **2** (2.52 g, 10 mmol) and 2-bromopropiophenone (1.64 ml, 11 mmol). The reaction mixture was heated for 2 h. Yield 89%, mp 157°C (propan-2-ol), $C_{25}H_{20}O_4$. IR spectrum (KBr, cm^{-1}): 3040, 1716, 1692, 1592, 1548, 1442, 1386, 1273, 1200, 1150, 985, 840, 745. PMR spectrum (300 MHz, deuteroacetone, δ, ppm): 1.72 (3H, d, α-CH_3), 2.36 (3H, s, CH_3-8), 6.01 (1H, q, COCHO), 6.13 (1H, s, H-3), 6.84 (1H, d, J = 8.5 Hz, H-6), 7.21 (1H, d, J = 8.5 Hz, H-5), 7.52 (5H, m, Ph-4), 7.62 (3H, m, H-3,4,5 PhCO), 8.11 (2H, m, H-2,6 PhCO).

7-(2-Oxo-2-phenylethoxy)-4-phenylcoumarin (10) was prepared analogously to **4** using **1** (2.38 g, 10 mmol) and α-bromoacetophenone (2.19 g, 11 mmol). The reaction mixture was heated for 1 h. Yield 89%, mp 156°C (propan-2-ol), $C_{23}H_{16}O_4$. IR spectrum (KBr, cm^{-1}): 3045, 1712, 1692, 1595, 1545, 1436, 1370, 1280, 1260, 1200, 1150, 1110, 997, 962, 830, 746. PMR spectrum (300 MHz, deuteroacetone, δ, ppm): 5.72 (2H, s, $COCH_2O$), 6.15 (1H, s, H-3), 6.98 (1H, dd, J = 2.0 and 8.5 Hz, H-6), 7.03 (1H, d, J = 2.0 Hz, H-8), 7.41 (1H, d, J = 8.5 Hz, H-5), 7.58 (5H, m, Ph-4), 7.65 (3H, m, H-3,4,5 PhCO), 8.10 (2H, m, H-2,6 PhCO).

8-Methyl-7-(2-oxo-2-phenylethoxy)-4-phenylcoumarin (11) was prepared analogously to **4** using **2** (2.52 g, 10 mmol) and α-bromoacetophenone (2.19 g, 11 mmol). The reaction mixture was heated for 1 h. Yield 95%, mp 186°C (propan-2-ol), $C_{24}H_{18}O_4$. IR spectrum (KBr, cm^{-1}): 3040, 1716, 1690, 1600, 1550, 1435, 1377, 1275, 1262, 1210, 1130, 1005, 955, 840, 760. PMR spectrum (300 MHz, deuteroacetone, δ, ppm): 2.38 (3H, s, CH_3-8), 5.73 (2H, s, $COCH_2O$), 6.15 (1H, s, H-3), 6.96 (1H, d, J = 8.5 Hz, H-6), 7.25 (1H, d, J = 8.5 Hz, H-5), 7.54 (5H, m, Ph-4), 7.63 (3H, m, H-3,4,5 PhCO), 8.08 (2H, m, H-2,6 PhCO).

7-[2-(4-Chlorophenyl)-2-oxoethoxy]-4-phenylcoumarin (12) was prepared analogously to **4** using **1** (2.38 g, 10 mmol) and α-bromo-4-chloroacetophenone (2.57 g, 11 mmol). The reaction mixture was heated for 1 h. Yield 90%, mp 191°C (propan-2-ol), $C_{23}H_{15}ClO_4$. IR spectrum (KBr, cm^{-1}): 3060, 1718, 1690, 1600, 1375, 1288, 1265, 1218, 1150, 1118, 982, 820, 765. PMR spectrum (300 MHz, DMSO-d_6, δ, ppm): 5.71 (2H, s, $COCH_2O$), 6.22 (1H, s, H-3), 6.98 (1H, dd, J = 2.0 and 8.5 Hz, H-6), 7.19 (1H, d, J = 2.0 Hz, H-8), 7.36 (1H, d, J = 8.5 Hz, H-5), 7.56 (5H, m, Ph-4), 7.64 (2H, d, J = 8 Hz, H-3,5 PhCO), 8.05 (2H, d, J = 8 Hz, H-2,6 PhCO).

7-[2-(4-Chlorophenyl)-2-oxoethoxy]-8-methyl-4-phenylcoumarin (13) was prepared analogously to **4** using **2** (2.52 g, 10 mmol) and α-bromo-4-chloroacetophenone (2.57 g, 11 mmol). The reaction mixture was heated for 1 h. Yield 92%, mp 219°C (propan-2-ol), $C_{24}H_{17}ClO_4$. IR spectrum (KBr, cm^{-1}): 3050, 1716, 1692, 1605, 1380, 1295, 1270, 1215, 1150, 1110, 980, 825, 750. PMR spectrum (300 MHz, DMSO-d_6, δ, ppm): 2.33 (3H, s, CH_3-8), 5.72 (2H, s, $COCH_2O$), 6.21 (1H, s, H-3), 6.96 (1H, d, J = 8.5 Hz, H-6), 7.18 (1H, d, J = 8.5 Hz, H-5), 7.55 (5H, m, Ph-4), 7.64 (2H, d, J = 8.5 Hz, H-3,5 PhCO), 8.04 (2H, d, J = 8.5 Hz, H-2,6 PhCO).

7-[2-(1,3-Benzodioxol-5-yl)-2-oxoethoxy]-4-phenylcoumarin (14) was prepared analogously to **4** using **1** (2.38 g, 10 mmol) and α-bromo-3,4-methylenedioxyacetophenone (2.67 g, 11 mmol). The reaction mixture was heated for 1 h. Yield 86%, mp 229°C (propan-2-ol), $C_{24}H_{16}O_6$. IR spectrum (KBr, cm^{-1}): 3040, 1718, 1698, 1600, 1550, 1375, 1272, 1195, 1140, 1100, 990, 830, 755. PMR spectrum (300 MHz, DMSO-d_6, δ, ppm): 5.62 (2H, s, $COCH_2O$), 6.17 (2H, s, OCH_2O), 6.24 (1H,

s, H-3), 6.98 (1H, dd, J = 2.0 and 8.5 Hz, H-6), 7.10 (1H, d, J = 8.5 Hz, H-7 benzodioxol), 7.19 (1H, d, J = 2.0 Hz, H-8), 7.36 (1H, d, J = 8.5 Hz, H-5), 7.53 (1H, d, J = 2.0 Hz, H-4 benzodioxol), 7.56 (5H, m, Ph-4), 7.69 (1H, dd, J = 2.0 and 8.5 Hz, H-6 benzodioxol).

7-[2-(1,3-Benzodioxol-5-yl)-2-oxoethoxy]-8-methyl-4-phenylcoumarin (15) was prepared analogously to **4** using **2** (2.52 g, 10 mmol) and α-bromo-3,4-methylenedioxyacetophenone (2.67 g, 11 mmol). The reaction mixture was heated for 1 h. Yield 88%, mp 204°C (propan-2-ol), $C_{25}H_{18}O_6$. IR spectrum (KBr, cm^{-1}): 3060, 1717, 1690, 1598, 1555, 1370, 1272, 1190, 1140, 1102, 990, 836, 760. PMR spectrum (300 MHz, DMSO-d_6, δ, ppm): 2.38 (3H, s, CH_3-8), 5.62 (2H, s, $COCH_2O$), 6.13 (2H, s, OCH_2O), 6.24 (1H, s, H-3), 6.96 (1H, d, J = 8.5 Hz, H-6), 7.08 (1H, d, J = 8.5 Hz, H-7 benzodioxol), 7.23 (1H, d, J = 8.5 Hz, H-5), 7.48 (1H, d, J = 2.0 Hz, H-4 benzodioxol), 7.55 (5H, m, Ph-4), 7.72 (1H, dd, J = 2.0 and 8.5 Hz, H-6 benzodioxol).

7-(2-Oxocyclohexyloxy)-4-phenylcoumarin (16). A solution of **1** (3.57 g, 15 mmol) in dry DMF (50 ml) was treated with freshly calcined potash (6.2 g, 45 mmol) and 2-chlorocyclohexanone (3.43 ml, 30 mmol). The reaction mixture was stirred vigorously and heated (75-80°C) for 24 h and then treated with 1 N H_2SO_4 (300 ml). The resulting precipitate was filtered off and crystallized from propan-2-ol. Yield 64%, mp 177°C (propan-2-ol), $C_{21}H_{18}O_4$. IR spectrum (KBr, cm^{-1}): 3055, 2935, 1710, 1688, 1590, 1545, 1440, 1368, 1272, 1200, 1150, 1105, 1064, 995, 828, 765. PMR spectrum (300 MHz, deuteroacetone, δ, ppm): 1.80-2.50 [8H, m, $(CH_2)_4$], 5.16 (1H, m, α-CH), 6.13 (1H, s, H-3), 6.85 (1H, dd, J = 2.0 and 8.5 Hz, H-6), 6.88 (1H, d, J = 2.0 Hz, H-8), 7.36 (1H, d, J = 8.5 Hz, H-5), 7.55 (5H, m, Ph-4).

8-Methyl-7-(2-oxocyclohexyloxy)-4-phenylcoumarin (17) was prepared analogously to **16** using **2** (3.78 g, 15 mmol). Yield 68%, mp 233°C (propan-2-ol), $C_{22}H_{20}O_4$. IR spectrum (KBr, cm^{-1}): 3060, 2940, 1715, 1692, 1595, 1550, 1438, 1370, 1270, 1202, 1151, 1101, 1065, 990, 830, 769. PMR spectrum (300 MHz, deuteroacetone, δ, ppm): 1.80-2.50 [8H, m, $(CH_2)_4$)], 2.36 (3H, s, CH_3-8), 5.19 (1H, m, α-CH), 6.21 (1H, s, H-3), 6.86 (1H, d, J = 8.5 Hz, H-6), 7.18 (1H, d, J = 8.5 Hz, H-5), 7.55 (5H, m, Ph-4).

7-Methyl-5-(2-oxopropoxy)-4-phenylcoumarin (18) was prepared analogously to **4** using **3** (2.52 g, 10 mmol). Yield 84%, mp 214°C (75% propan-2-ol), $C_{19}H_{16}O_4$. IR spectrum (KBr, cm^{-1}): 3050, 1716, 1620, 1590, 1445, 1364, 1245, 1130, 1065, 940, 879, 790, 770. PMR spectrum (300 MHz, deuteroacetone, δ, ppm): 1.70 (3H, s, CH_3CO), 2.40 (3H, s, CH_3-7), 4.43 (2H, s, $COCH_2O$), 6.04 (1H, s, H-3), 6.68 (1H, d, J = 2 Hz, H-6), 6.91 (1H, d, J = 2 Hz, H-9), 7.42 (5H, m, Ph-4).

7-Methyl-5-(1-methyl-2-oxopropoxy)-4-phenylcoumarin (19) was prepared analogously to **4** using **3** (2.52 g, 10 mmol) and 3-chloro-2-butanone (1.11 ml, 11 mmol). The reaction mixture was heated for 4 h. Yield 81%, mp 117°C (75% propan-2-ol), $C_{20}H_{18}O_4$. IR spectrum (KBr, cm^{-1}): 3060, 1714, 1625, 1598, 1440, 1370, 1242, 1130, 1065, 945, 871, 791, 770. PMR spectrum (300 MHz, deuteroacetone, δ, ppm): 0.86 (3H, d, α-CH_3), 1.86 (3H, s, CH_3CO), 2.37 (3H, s, CH_3-7), 4.66 (1H, q, COCHO), 6.01 (1H, s, H-3), 6.47 (1H, d, J = 2 Hz, H-6), 6.85 (1H, d, J = 2 Hz, H-8), 7.42 (5H, m, Ph-4).

7-Methyl-5-(2-oxo-2-phenylethoxy)-4-phenylcoumarin (20) was prepared analogously to **4** using **3** (2.52 g, 10 mmol) and α-bromoacetophenone (2.19 g, 11 mmol). The reaction mixture was heated for 1 h. Yield 85%, mp 132°C (propan-2-ol), $C_{24}H_{18}O_4$. IR spectrum (KBr, cm^{-1}): 3055, 1716, 1675, 1630, 1595, 1450, 1358, 1280, 1255, 1224, 1208, 1110, 938, 882, 865, 830, 780, 745. PMR spectrum (300 MHz, deuteroacetone, δ, ppm): 2.35 (3H, s, CH_3-7), 5.15 (2H, s, $COCH_2O$), 6.00 (1H, s, H-3), 6.70 (1H, d, J = 2 Hz, H-6), 6.84 (1H, d, J = 2 Hz, H-8), 7.30 (5H, m, Ph-4), 7.55 (3H, m, H-3,4,5 PhCO), 7.82 (2H, m, H-2,6 PhCO).

5-[2-(4-Chlorophenyl)-2-oxoethoxy]-7-methyl-4-phenylcoumarin (21) was prepared analogously to **4** using **3** (2.52 g, 10 mmol) and α-bromo-4-chloroacetophenone (2.57 g, 11 mmol). The reaction mixture was heated for 1 h. Yield 91%, mp 174°C (propan-1-ol), $C_{24}H_{17}ClO_4$. IR spectrum (KBr, cm^{-1}): 3050, 1716, 1685, 1605, 1462, 1370, 1282, 1265, 1220, 1150, 990, 830, 768. PMR spectrum (300 MHz, DMSO-d_6, δ, ppm): 2.33 (3H, s, CH_3-7), 5.13 (2H, s, $COCH_2O$), 6.03 (1H, s, H-3), 6.72 (1H, d, J = 2 Hz, H-6), 6.91 (1H, d, J = 2 Hz, H-8), 7.27 (5H, m, Ph-4), 7.54 (2H, d, J = 8 Hz, H-3,5 PhCO), 7.77 (2H, d, J = 8.5 Hz, H-2,6 PhCO).

7-Methyl-5-(2-oxocyclohexyloxy)-4-phenylcoumarin (22) was prepared analogously to **16** using **3** (3.78 g, 15 mmol). Yield 52%, mp 189°C (propan-2-ol), $C_{22}H_{20}O_4$. IR spectrum (KBr, cm^{-1}): 3060, 2945, 1714, 1695, 1591, 1550, 1440, 1375, 1270, 1195, 1150, 1105, 1075, 995, 835, 765. PMR spectrum (300 MHz, deuteroacetone, δ, ppm): 1.30-2.50 [8H, m, $(CH_2)_4$], 2.32 (3H, s, CH_3-7), 4.92 (1H, m, α-CH), 6.01 (1H, s, H-3), 6.52 (1H, d, J = 2 Hz, H-6), 6.85 (1H, d, J = 2 Hz, H-8), 7.31 (5H, m, Ph-4).

5-Phenyl-7H-furo[3,2-g]chromen-7-ones (23-36) and 9-phenyl-7H-furo[2,3-f]chromen-7-ones (37-41). A solution or suspension of ketone **4-22** (6 mmol) in isopropanol (50 ml) was treated with 1 N NaOH (50 ml). The reaction mixture was heated for 3-4 h until the ketone dissolved totally (the course of the reaction was monitored by TLC) and added to 1 N H_2SO_4

(300 ml). The resulting precipitate was filtered off and crystallized from propan-2-ol.

3-Methyl-5-phenyl-7H-furo[3,2-g]chromen-7-one (23): $C_{18}H_{12}O_3$, yield 78%, mp 161°C. IR spectrum (KBr, cm^{-1}): 1716, 1600, 1551, 1430, 1340, 1255, 1160, 1125, 1050, 940, 842, 760. PMR spectrum (300 MHz, DMSO-d_6, δ, ppm): 2.13 (3H, s, CH_3-3), 6.36 (1H, s, H-6), 7.54 (1H, s, H-4), 7.61 (5H, m, Ph-5), 7.76 (1H, s, H-9), 7.88 (1H, s, H-2).

3,9-Dimethyl-5-phenyl-7H-furo[3,2-g]chromen-7-one (24): $C_{19}H_{14}O_3$, yield 82%, mp 221°C. IR spectrum (KBr, cm^{-1}): 1715, 1606, 1550, 1432, 1346, 1254, 1162, 1128, 1055, 941, 840, 760. PMR spectrum (300 MHz, DMSO-d_6, δ, ppm): 2.12 (3H, s, CH_3-3), 2.53 (3H, s, CH_3-9), 6.32 (1H, s, H-6), 7.36 (1H, s, H-4), 7.59 (5H, m, Ph-5), 7.86 (1H, s, H-2).

2,3-Dimethyl-5-phenyl-7H-furo[3,2-g]chromen-7-one (25): $C_{19}H_{14}O_3$, yield 75%, mp 183°C. IR spectrum (KBr, cm^{-1}): 1718, 1601, 1550, 1434, 1341, 1250, 1162, 1127, 1051, 945, 840, 765. PMR spectrum (300 MHz, DMSO-d_6, δ, ppm): 2.03 (3H, s, CH_3-3), 2.37 (3H, s, CH_3-2), 6.27 (1H, s, H-6), 7.36 (1H, s, H-4), 7.55 (5H, m, Ph-5), 7.57 (1H, s, H-9).

2,3,9-Trimethyl-5-phenyl-7H-furo[3,2-g]chromen-7-one (26): $C_{20}H_{16}O_3$, yield 72%, mp 231°C. IR spectrum (KBr, cm^{-1}): 1718, 1600, 1555, 1431, 1360, 1340, 1251, 1168, 1120, 1055, 941, 840, 761. PMR spectrum (300 MHz, DMSO-d_6, δ, ppm): 2.02 (3H, s, CH_3-3), 2.39 (3H, s, CH_3-2), 2.48 (3H, s, CH_3-9), 6.28 (1H, s, H-6), 7.20 (1H, s, H-4), 7.58 (5H, m, Ph-5).

2-Methyl-3,5-diphenyl-7H-furo[3,2-g]chromen-7-one (27): $C_{24}H_{16}O_3$, yield 84%, mp 211°C. IR spectrum (KBr, cm^{-1}): 1718, 1609, 1571, 1429, 1360, 1325, 1245, 1155, 1129, 1062, 941, 830, 754. PMR spectrum (300 MHz, DMSO-d_6, δ, ppm): 2.53 (3H, s, CH_3-2), 6.37 (1H, s, H-6), 7.36-7.44 (5H, m, Ph-3), 7.51 (1H, s, H-4), 7.76 (1H, s, H-9).

2,9-Dimethyl-3,5-diphenyl-7H-furo[3,2-g]chromen-7-one (28): $C_{25}H_{18}O_3$, yield 86%, mp 262°C. IR spectrum (KBr, cm^{-1}): 1716, 1600, 1565, 1432, 1364, 1322, 1249, 1159, 1120, 1068, 940, 835, 750. PMR spectrum (300 MHz, DMSO-d_6, δ, ppm): 2.54 (3H, s, CH_3-2), 2.57 (3H, s, CH_3-9), 6.31 (1H, s, H-6), 7.35 (1H, s, H-4), 7.40-7.45 (5H, m, Ph-3), 7.53 (1H, s, H-4).

3,5-Diphenyl-7H-furo[3,2-g]chromen-7-one (29): $C_{23}H_{14}O_3$, yield 83%, mp 191°C. IR spectrum (KBr, cm^{-1}): 1712, 1605, 1560, 1434, 1364, 1332, 1251, 1158, 1132, 1056, 940, 839, 758. PMR spectrum (300 MHz, DMSO-d_6, δ, ppm): 6.40 (1H, s, H-6), 7.36 (1H, m, H-4 of Ph-3), 7.45 (2H, m, H-3 and H-5 of Ph-3), 7.56 (2H, m, H-2 and H-6 of Ph-3), 7.60 (5H, m, Ph-5), 7.82 (1H, s, H-4), 7.89 (1H, s, H-9), 8.43 (1H, s, H-2).

9-Methyl-3,5-diphenyl-7H-furo[3,2-g]chromen-7-one (30): $C_{24}H_{16}O_3$, yield 79%, mp 248°C. IR spectrum (KBr, cm^{-1}): 1717, 1600, 1560, 1440, 1360, 1338, 1250, 1161, 1130, 1060, 945, 842, 762. PMR spectrum (300 MHz, DMSO-d_6, δ, ppm): 2.58 (3H, s, CH_3-9), 6.36 (1H, s, H-6), 7.35 (1H, m, H-4 of Ph-3), 7.43 (2H, m, H-3 and H-5 of Ph-3), 7.53 (2H, m, H-2 and H-6 of Ph-3), 7.56 (5H, m, Ph-5), 7.64 (1H, s, H-4), 8.41 (1H, s, H-2).

3-(4-Chlorophenyl)-5-phenyl-7H-furo[3,2-g]chromen-7-one (31): $C_{23}H_{13}ClO_3$, yield 88%, mp 223°C. IR spectrum (KBr, cm^{-1}): 1719, 1625, 1560, 1486, 1441, 1342, 1316, 1266, 1162, 1132, 1090, 1069, 948, 860, 827, 791. PMR spectrum (300 MHz, DMSO-d_6, δ, ppm): 6.40 (1H, s, H-6), 7.51 (2H, d, J = 9 Hz, H-3 and H-5 of Ph-3), 7.59 (2H, d, J = 9 Hz, H-2 and H-6 of Ph-3), 7.61 (5H, m, Ph-5), 7.80 (1H, s, H-4), 7.90 (1H, s, H-9), 8.47 (1H, s, H-2).

3-(4-Chlorophenyl)-9-methyl-5-phenyl-7H-furo[3,2-g]chromen-7-one (32): $C_{24}H_{15}ClO_3$, yield 91%, mp 267°C. IR spectrum (KBr, cm^{-1}): 1717, 1620, 1561, 1490, 1435, 1342, 1310, 1260, 1169, 1125, 1088, 1060, 950, 860, 790. PMR spectrum (300 MHz, DMSO-d_6, δ, ppm): 2.58 (3H, s, CH_3-9), 6.38 (1H, s, H-6), 7.51 (2H, d, J = 9 Hz, H-3 and H-5 of Ph-3), 7.56 (2H, d, J = 9 Hz, H-2 and H-6 of Ph-3), 7.59 (5H, m, Ph-5), 7.60 (1H, s, H-4), 8.46 (1H, s, H-2).

3-(1,3-Benzodioxol-5-yl)-5-phenyl-7H-furo[3,2-g]chromen-7-one (33): $C_{24}H_{14}O_5$, yield 76%, mp 192°C. IR spectrum (KBr, cm^{-1}): 1716, 1615, 1565, 1430, 1378, 1325, 1250, 1151, 1130, 1069, 968, 830, 772. PMR spectrum (300 MHz, DMSO-d_6, δ, ppm): 6.05 (2H, s, OCH_2O), 6.40 (1H, s, H-6), 6.97 (1H, d, J = 8.5 Hz, H-7 of benzodioxol), 7.03 (1H, dd, J = 2.0 and 8.5 Hz, H-6 of benzodioxol), 7.14 (1H, d, J = 2.0 Hz, H-4 of benzodioxol), 7.63 (5H, m, Ph-5), 7.78 (1H, s, H-4), 7.87 (1H, s, H-9), 8.36 (1H, s, H-2).

3-(1,3-Benzodioxol-5-yl)-9-methyl-5-phenyl-7H-furo[3,2-g]chromen-7-one (34): $C_{25}H_{16}O_5$, yield 83%, mp 239°C. IR spectrum (KBr, cm^{-1}): 1718, 1619, 1555, 1440, 1365, 1325, 1257, 1140, 1125, 1060, 961, 849, 752. PMR spectrum (300 MHz, DMSO-d_6, δ, ppm): 2.57 (3H, s, CH_3-9), 6.03 (2H, s, OCH_2O), 6.33 (1H, s, H-6), 6.96 (1H, d, J = 8.5 Hz, H-7 of benzodioxol), 7.06 (1H, dd, J = 2.0 and 8.5 Hz, H-6 of benzodioxol), 7.14 (1H, d, J = 2.0 Hz, H-4 of benzodioxol), 7.58 (5H, m, Ph-5), 7.60 (1H, s, H-4), 8.27 (1H, s, H-2).

4-Phenyl-6,7,8,9-tetrahydro-2H-benzo[4,5]furo[3,2-g]chromen-2-one (35): $C_{21}H_{16}O_3$, yield 72%, mp 234°C. IR spectrum (KBr, cm^{-1}): 3035, 2920, 1716, 1696, 1615, 1556, 1445, 1377, 1336, 1288, 1240, 1134, 1119, 982, 949, 878, 790, 768, 709. PMR spectrum (300 MHz, DMSO-d_6, δ, ppm): 1.75 (2H, m, H-7), 1.87 (2H, m, H-8), 2.60 (2H, m, H-6), 2.73 (2H, m, H-9), 6.32 (1H, s, H-3), 7.38 (1H, s, H-5), 7.59 (5H, m, Ph-4), 7.67 (1H, s, H-11).

11-Methyl-4-phenyl-6,7,8,9-tetrahydro-2H-benzo[4,5]furo[3,2-g]chromen-2-one (36): $C_{22}H_{18}O_3$, yield 78%, mp

268°C. IR spectrum (KBr, cm^{-1}): 3040, 2920, 1718, 1690, 1600, 1560, 1440, 1382, 1330, 1271, 1236, 1130, 1110, 980, 941, 880, 775. PMR spectrum (300 MHz, DMSO-d_6, δ, ppm): 1.73 (2H, m, H-7), 1.85 (2H, m, H-8), 2.46 (3H, s, CH_3-11), 2.60 (2H, m, H-6), 2.73 (2H, m, H-9), 6.28 (1H, s, H-3), 7.21 (1H, s, H-5), 7.59 (5H, m, Ph-4).

3,4-Dimethyl-9-phenyl-7H-furo[2,3-f]chromen-7-one (37): $C_{19}H_{14}O_3$, yield 72%, mp 186°C. IR spectrum (KBr, cm^{-1}): 1718, 1690, 1595, 1556, 1480, 1427, 1360, 1225, 1190, 1130, 1115, 1062, 948, 874, 755. PMR spectrum (300 MHz, DMSO-d_6, δ, ppm): 2.32 (3H, s, CH_3-3), 2.70 (3H, s, CH_3-4), 6.26 (1H, s, H-8), 7.18 (1H, s, H-5), 7.49 (5H, m, Ph-5), 7.52 (1H, s, H-2).

2,3,4-Trimethyl-9-phenyl-7H-furo[2,3-f]chromen-7-one (38): $C_{20}H_{16}O_3$, yield 70%, mp 162°C. IR spectrum (KBr, cm^{-1}): 1716, 1695, 1610, 1550, 1482, 1431, 1360, 1232, 1191, 1115, 1068, 954, 879, 755. PMR spectrum (300 MHz, DMSO-d_6, δ, ppm): 2.02 (3H, s, CH_3-2), 2.24 (3H, s, CH_3-3), 2.66 (3H, s, CH_3-4), 6.25 (1H, s, H-8), 7.10 (1H, s, H-5), 7.50 (5H, m, Ph-5).

4-Methyl-3,9-diphenyl-7H-furo[2,3-f]chromen-7-one (39): $C_{24}H_{16}O_3$, yield 84%, mp 216°C. IR spectrum (KBr, cm^{-1}): 3055, 1718, 1695, 1600, 1561, 1482, 1444, 1367, 1217, 1180, 1126, 1101, 1059, 940, 894, 865, 762. PMR spectrum (300 MHz, DMSO-d_6, δ, ppm): 2.24 (3H, s, CH_3-4), 6.33 (1H, s, H-8), 7.25 (1H, s, H-5), 7.44 (5H, m, Ph-3), 7.56 (5H, m, Ph-9), 7.81 (1H, s, H-2).

3-(4-Chlorophenyl)-4-methyl-9-phenyl-7H-furo[2,3-f]chromen-7-one (40): $C_{24}H_{15}ClO_3$, yield 86%, mp 225°C. IR spectrum (KBr, cm^{-1}): 1716, 1610, 1565, 1475, 1450, 1367, 1215, 1180, 1136, 1118, 1059, 932, 875, 755. PMR spectrum (300 MHz, DMSO-d_6, δ, ppm): 2.26 (3H, s, CH_3-4), 6.32 (1H, s, H-8), 7.30 (2H, d, J = 9 Hz, H-3 and H-5 of Ph-3), 7.51 (2H, d, J = 9 Hz, H-2 and H-6 of Ph-3), 7.54 (5H, m, Ph-9), 7.84 (1H, s, H-2).

6-Methyl-1-phenyl-7,8,9,10-tetrahydro-3H-benzo[4,5]furo[2,3-f]chromen-3-one (41): $C_{22}H_{18}O_3$, yield 69%, mp 186°C. IR spectrum (KBr, cm^{-1}): 3040, 2930, 1718, 1690, 1605, 1550, 1440, 1370, 1330, 1262, 1228, 1135, 1105, 970, 886, 779. PMR spectrum (300 MHz, DMSO-d_6, δ, ppm): 1.73 (4H, m, H-8, H-9), 2.34 (2H, m, H-10), 2.62 (3H, s, CH_3-6), 2.78 (2H, m, H-7), 6.26 (1H, s, H-2), 7.13 (1H, s, H-5), 7.49 (5H, m, Ph-1).

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