A Photochemical Synthesis of 3-Aryl-1-methylquinolinones

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A number of fluorescent 3-aryl-1-methylquinolinones **3** were synthesized by the regiospecific photocoupling reaction of 3-halo-1-methylquinolinones **1** with aromatic and heteroaromatic compounds **2**. An unusual photocoupling product **4** was obtained in the photolysis of 3-iodo-1-methylquinolinone in the presence of benzene. The structure of **4** was unequivocally established by an X-ray crystallographic analysis.

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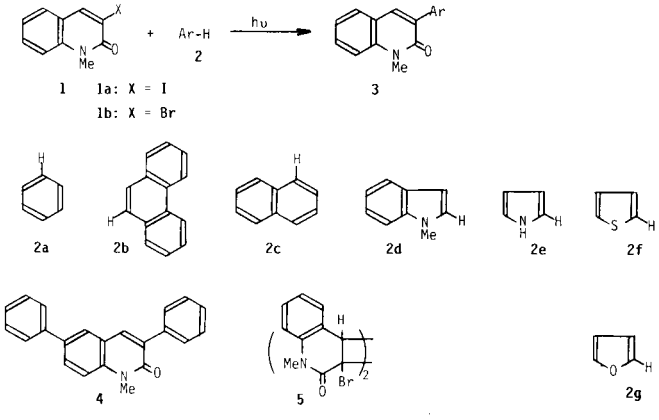
Quinolinone and its derivatives have been known as growth hormones, antibiotics, fragrances, and fluorescent materials [1,2]. Although various photochemical behavior including photodimerization [3], photocycloaddition [4,5] and photoprenylation [6] have been reported, little attention has been drawn to the photochemistry of haloqinolinones. In a continuation of our work on the synthetic use of the photocoupling of haloaromatics with arenes [7], we report here the photocoupling reaction of 3-halo-1-methylquinolinones with an aromatic or a heteroaromatic compound leading to 3-aryl-1-methylquinolinones.



Photolysis of 3-halo-1-methylquinolinones **1** (**1a**, X = I; **1b**, X = Br) was carried out with a 15 W low-pressure mercury lamp in the presence of a large excess of an aromatic or a heteroaromatic compound, such as benzene (**2a**), phenanthrene (**2b**), naphthalene (**2c**), *N*-methylindole (**2d**), pyrrole (**2e**), thiophene (**2f**) and furan (**2g**), in acetonitrile and/or acetone at ambient temperature (15-25°). The major products were the corresponding 3-aryl-1-methylquinolinones **3** except the cases of **1a**/**2a**, **1a**/**2c**, **1b**/**2a** and **1b**/**2c**. The results are summarized in Table 1. The structures of the new compounds were confirmed by ^{1}H-nmr, uv, ir and mass spectroscopy and microanalytical data. All the 3-aryl-1-methylquinolinones **3** showed a relatively strong fluorescence indicating that these compounds can be used as fluorescent materials.

Table 1

Photoreaction of 3-Halo-1-methylquinolinones 1 with Aromatic and Heteroaromatic Compounds 2

1	2	solvent	Irradiation time (hour)	Product (% yield)
1a	**2a**	acetonitrile	66	**4** (36)
1a	**2b**	acetone	72	**3b** (20)
1a	**2c**	acetonitrile [a]	75	No reaction
1a	**2d**	acetonitrile	36	**3d** (49)
1b	**2a**	acetonitrile	66	**5** (22)
1b	**2b**	acetone	70	**3b** (15)
1b	**2c**	acetone	36	**5** (26)
1b	**2e**	acetonitrile	24	**3e** (59)
1b	**2f**	acetonitrile	48	**3f** (17)
1b	**2g**	acetonitrile	24	**3g** (38)

[a] Use of 1:1 acetonitrile/acetone gave similar results.

Photolysis of 3-iodo-1-methylquinolinone (**1a**) in the presence of benzene (**2a**) in acetonitrile gave an unusual product **4** in which the 6-hydrogen of **1a** was replace by a phenyl group in addition to the usual 3-phenylation. The structure of **4** was unequivocally established by an X-ray crystallographic analysis (Figure 1 and Tables 2-4). The mechanism for the surprising formation of **4** remains to be elucidated. In case of **1a**/**2c** no reaction occurred at all. On the other hand, photolysis of 3-bromo-1-methylquinolinone (**1b**) in the presence of benzene (**2a**) or naphthalene (**2c**) gave no 3-arylated product **3**, but a dimer **5** of **1b** as

the major product. Photoirradiation of an acetone solution of **1a** or **1b** was carried out as a control experiment. A photoreaction did not occur for **1a**, whereas a photodimerization resulting in the formation of the dimer **5** was observed for **1b**.

Table 2

Final Atomic Coordinat s for Non-Hydrogen Atoms with Estimated Standard Deviation in Parentheses

Atom	X	Y	Z
O1	1.0485(3)	-0.035(2)	0.0945(3)
N1	0.9602(4)	0.129(2)	0.0717(4)
C1	1.0068(5)	-0.029(3)	0.1041(5)
C2	1.0003(4)	-0.182(2)	0.1465(5)
C3	0.9474(5)	-0.180(3)	0.1489(5)
C4	0.8483(4)	-0.035(3)	0.1172(5)
C5	0.8037(4)	0.116(2)	0.0844(4)
C6	0.8125(5)	0.277(2)	0.0487(5)
C7	0.8651(4)	0.286(3)	0.0450(5)
C8	0.9076(4)	0.129(3)	0.0759(5)
C9	0.9010(4)	-0.031(3)	0.1126(5)
C10	0.9679(4)	0.289(3)	0.0318(5)
C11	1.0492(4)	-0.334(2)	0.1850(5)
C12	1.0399(5)	-0.551(3)	0.2057(5)
C13	1.0839(6)	-0.690(3)	0.2456(6)
C14	1.1402(5)	-0.617(3)	0.2682(6)
C15	1.1522(5)	-0.415(3)	0.2485(5)
C16	1.1071(4)	-0.261(3)	0.2079(5)
C17	0.7483(5)	0.112(2)	0.0907(5)
C18	0.7354(5)	-0.079(3)	0.1167(6)
C19	0.6847(5)	-0.079(3)	0.1239(6)
C20	0.6467(5)	0.106(3)	0.1037(6)
C21	0.6582(5)	0.285(3)	0.0780(7)
C22	0.7086(5)	0.297(3)	0.0705(6)

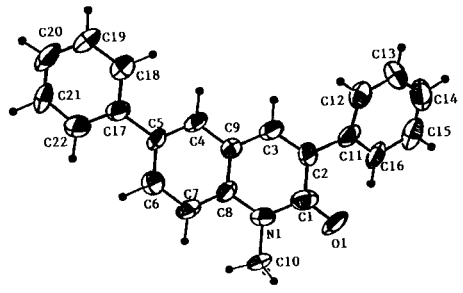


Figure 1. Molecular structure of **4**.

Table 3

Bond Lengths (A) of **4** with Estimated Standard Deviations in Parentheses

O1-C1	1.212(7)	C6-H6	1.052(7)	C15-C16	1.44(2)
N1-C1	1.416(8)	C7-C8	1.344(8)	C15-H15	0.996(8)
N1-C8	1.413(7)	C7-H7	1.024(6)	C16-H16	0.991(7)
N1-C10	1.443(7)	C8-C9	1.368(8)	C17-C18	1.386(9)
C1-C2	1.457(8)	C10-H10-1	0.962(6)	C17-C22	1.39(1)
C2-C3	1.395(8)	C10-H10-2	0.977(8)	C18-C19	1.403(9)
C2-C11	1.466(9)	C10-H10-3	0.976(7)	C18-H18	1.044(8)
C3-C9	1.405(8)	C11-C12	1.40(1)	C19-C20	1.36(1)
C3-H3	0.984(6)	C11-C16	1.392(8)	C19-H19	0.956(8)
C4-C5	1.366(8)	C12-C13	1.371(9)	C20-C21	1.31(1)
C4-C9	1.419(8)	C12-H12	0.977(7)	C20-H20	0.965(7)
C4-H4	1.014(7)	C13-H14	1.36(2)	C21-H22	1.402(9)
C5-C6	1.377(8)	C13-H13	0.957(9)	C21-H21	1.039(8)
C5-C17	1.511(7)	C14-C15	1.34(2)	C22-H22	1.036(7)
C6-C7	1.408(8)	C14-H14	1.011(9)		

Table 4

Bond Angles (°) of **4** with Estimated Standard Deviations in Parenthsis

C1-N1-C8	122.7(7)	N1-C8-C7	120.5(7)	C14-C15-C16	122.4(8)
C1-N1-C10	116.7(5)	N1-C8-C9	118.8(7)	C14-C15-H15	117(2)
C8-N1-C10	120.3(6)	C7-C8-C9	120.7(6)	C16-C15-H15	120(2)
O1-C1-N1	119.8(7)	C3-C9-C4	119.7(7)	C11-C16-C15	118.4(7)
O1-C1-C2	123.4(7)	C3-C9-C8	120.5(7)	C11-C16-H16	123.0(8)
N1-C1-C2	116.7(6)	C4-C9-C8	119.7(7)	C15-C16-H16	118.6(7)
C1-C2-C3	118.6(7)	N1-C10-H10-1	127.7(7)	C15-C17-C18	120.9(8)
C1-C2-C11	119.1(6)	N1-C10-H10-2	108.0(6)	C15-C17-C22	121.3(7)
C3-C2-C11	122.4(7)	N1-C10-H10-3	108.6(5)	C18-C17-C22	117.7(6)
C2-C3-C9	122.2(6)	H10-1-C10-H10-2	102.7(5)	C17-C18-C19	120.7(8)
C2-C3-H3	117.7(7)	H10-1-C10-H10-3	102.7(6)	C17-C18-H18	120.5(7)
C9-C3-H3	120.0(7)	H10-2-C10-H10-3	105.2(8)	C19-C18-H18	118.7(8)
C5-C4-C9	120.6(6)	C2-C11-C12	121.4(6)	C18-C19-C20	120.0(8)
C5-C4-H4	120.6(6)	C2-C11-C16	122.0(8)	C18-C19-H19	124.9(9)
C9-C4-H4	118.6(7)	C12-C11-C16	116.3(8)	C20-C19-H19	114.5(8)
C4-C5-C6	117.7(6)	C11-C12-C13	123.7(7)	C19-C20-C21	119.5(8)
C4-C5-C17	119.7(6)	C11-C12-H12	115.0(8)	C9-C20-H20	125(1)
C6-C5-C17	122.5(7)	C13-C12-H12	121.4(9)	C21-C20-H20	115(1)
C5-C6-C7	122.0(6)	C12-C13-C14	119.8(8)	C20-C21-C22	123.0(8)
C5-C6-H6	118.5(7)	C12-C13-H13	117.5(9)	C20-C21-H21	118.2(9)
C7-C6-H6	119.4(7)	C14-C13-H13	123(1)	C22-C21-H21	117(1)
C6-C7-C8	119.2(6)	C13-C14-C15	119.2(9)	C17-C22-C21	119.1(8)
C6-C7-H7	119.1(7)	C13-C14-H14	118(1)	C17-C22-H22	119.8(7)
C8-C7-H7	121.6(7)	C15-C14-H14	123(2)	C21-C22-H22	120.8(8)

EXPERIMENTAL

All melting points are uncorrected. The ^{1}H-nmr and mass spectra were measured on a JEOL PMX-60 and a 7070E-HE spectrometers respectively. The ir, uv and fluorescence spectra were measured on a PYE UNICAM sp 3-300, a Shimadzu UV-240 and a Shimadzu RF-540 spectrophotometers, respectively. Column chromatography and preparative tlc were carried out on silica gel of Qing Dao 300 and F_{254}, respectively. 3-Halo-1-methylquinolinones **3** were prepared according to the literature procedure [8]. Other substrates were commercially available.

Photoreaction of **1a** with **2a**. 3,6-Diphenyl-1-methylquinolinone **4**.

A solution of 3-iodo-1-methylquinolinone **1a** [8] (1.007 g, 3.5 mmoles) in benzene **2a** (170 ml) and acetone (160 ml) was irradiated with a 15 W low-pressure mercury lamp (Quartz vessel) at room temperature for 66 hours. After the removal of the solvents under reduced pressure, the residue was chromatographed on silica gel with ethyl acetate-petroleum ether (1:2) elution to give **4** (36%), mp 136-137°; ir (potassium bromide): 1640, 1597 and 1570 cm^{-1}; ^{1}H-nmr (deuteriochloroform): δ 3.75 (s, 3H, *N*-methyl protons), 7.20-7.90 (m, 14H, aromatic protons); ms: m/e 311 (M$^+$), 282, 239, 204, 155; uv (acetonitrile): λ max 267.3 nm (ε 5.11 x 10^4); fluorescence maximum (acetonitrile): 426.7 nm (excitation at 265.8 nm).

Anal. Calcd. for $C_{22}H_{17}NO$: C, 84.86; H, 5.50; N, 4.50. Found: C, 84.74; H, 5.55; N, 4.53.

Photoreaction of **1a** with **2b**. 1-Methyl-3-(9-phenanthryl)quinolinone (**3b**).

A solution of **1a** (0.861 g, 3 mmoles) and phenanthrene **2b** (0.804 g, 4.5 mmoles) in acetone (330 ml) was irradiated for 72 hours as mentioned above. After the removal of the solvent under reduced pressure, the residue was chromatographed on a silica gel column with ethyl acetate-petroleum ether (1:2) elution to give **3b** (20%), mp 55-58°; ir (potassium bromide): 1714, 1640 and 1590 cm^{-1}; ^{1}H-nmr (deuteriochloroform): δ 3.80 (s, 3H, *N*-methyl protons), 7.10-7.90 (m, 11H, aromatic protons), 7.54 (broad s, 1H, 9-phenanthryl 10-H), 8.45-8.75 (m, 2H, aromatic protons); ms: m/e 335 (M$^+$), 318, 304, 291, 167, 145; uv (acetonitrile): λ max 227.3 nm (ε 6.24 x 10^4); fluorescence maximum (acetonitrile): 408.1 nm (excitation at 221 nm).

Anal. Calcd. for $C_{24}H_{17}NO$: C, 85.97; H, 5.07; N, 4.18. Found: C, 85.64; H, 5.03; N, 4.21.

Photoreaction of **1a** with **2c**.

A solution of **1a** (0.861 g, 3 mmoles) and naphthalene **2c** (0.577 g, 4.5 mmoles) in acetonitrile (300 ml) or 1:1 acetone-acetonitrile (300 ml) was irradiated for 75 hours as mentioned above. A photoreaction was not observed by tlc analysis of the irradiated mixture.

Photoreaction of **1a** with **2d**. 1-Methyl-3-(1-methyl-3-indolyl)-quinolinone **3d**.

A solution of **1a** (0.861 g, 3 mmoles) and 1-methylindole **2d** (1.200 g, 9 mmoles) in acetonitrile (300 ml) was irradiated for 36 hours as mentioned above. After the removal of the solvent under reduced pressure, the residue was chromatographed on a silica gel column with ethyl acetate-petroleum ether (1:4) elution to give **3d** (49%), mp 298-300°; ir (potassium bromide): 1700 and 1615 cm^{-1}; ^{1}H-nmr (deuteriochloroform): δ 3.80 (s, 6H, *N*-methyl protons), 6.50 (broad s, 1H, indole β-H), 7.00-7.80 (m, 9H, aromatic protons); ms: m/e 288 (M$^+$), 252, 210, 179, 108; uv (acetonitrile): λ max 233.9 nm (δ 3.04 x 10^4); fluorescence maximum (acetonitrile): 480.7 (excitation at 234 nm).

Anal. Calcd. for $C_{19}H_{16}N_2O$: C, 79.17; H, 5.56; N, 9.72. Found: C, 79.01; H, 5.53; N, 9.78.

Photoreaction of **1b** with **2a**. A dimer **5** of 3-Bromo-1-methylquinolinone **1b**.

A solution of 3-bromo-1-methylquinolinone **1b** (0.700 g, 3 mmoles) in benzene **2a** (170 ml) and acetone (160 ml) was irradiated for 66 hours as mentioned above. After the removal of the solvent under reduced pressure, a yellowish solid separated out. Recrystallization from 95% ethanol gave a dimer **5** (22%), mp 259-261°; ir (potassium bromide): 1645 and 1592 cm^{-1}; ^{1}H-nmr (deuteriochloroform): δ 3.70-3.80 (m, 8H, *N*-methyl-H and C-H), 7.20-8.20 (m, 8H, aromatic protons); ms: m/e 474 (M$^+$), 396, 381, 367, 351, 316, 301; uv (acetonitrile): λ max 234.1 nm (ε 8.48 x 10^4); fluorescense maximum (acetonitrile): 419.1 nm (excitation at 234 nm).

Anal. Calcd. for $C_{20}H_{16}N_2O_2Br_2$: C, 50.45; H, 3.39; N, 5.48. Found; C, 50.23; H, 3.41; N, 5.95.

Photoreaction of **1b** with **2b**.

A solution of **1b** (0.700 g, 3 mmoles) and phenanthrene **2b** (0.804 g, 4.5 mmoles) in acetone (330 ml) was irradiated for 70 hours as mentioned above. Silica gel chromatography of the product mixture gave **3b** (15%).

Photoreaction of **1b** with **2c**.

A solution of **1b** (0.700 g, 3 mmoles) and naphthalene **2c** (1.200 g, 9 mmoles) in acetone (330 ml) was irradiated for 36 hours as mentioned above. After the removal of the solvent, under reduced pressure, a light yellow solid separated out. Recrystallization from 95% ethanaol gave **3c** (26%).

Photoreaction of **1b** with **2e**. 1-Methyl-3-(2-pyrrolyl)quinolinone **3e**.

A solution of **1b** (0.700 g, 3 mmoles) and pyrrole **2e** (0.600 g, 9 mmoles) in acetonitrile (300 ml) was irradiated for 24 hours as mentioned above. After the removal of the solvent under reduced pressure, the residue was chromatographed on a silica gel column with ethyl acetate-petroleum ether (1:4) elution to give **3e** (59%), mp 180-183°; ir (potassium bromide): 3372, 1630 and 1609 cm^{-1}; ^{1}H-nmr (deuteriochloroform): δ 3.65 (s, 3H, *N*-methyl protons), 6.00-6.30 (m, 2H, pyrrole β-protons), 6.70 (m, 1H, pyrrole α-H), 6.90-7.80 (m, 5H, aromatic protons), 7.85-8.00 (m, 1H, N-H); ms: m/e 224 (M$^+$), 194, 165, 138; uv (acetonitrile): λ max 237.1 nm (ε 1.22 x 10^4); fluorescence maximum (acetonitrile): 455.0 nm (excitation at 310 nm).

Anal. Calcd. for $C_{14}H_{12}N_2O$: C, 74.97; H, 5.39; N,, 12.49. Found: C, 74.66; H, 5.40; N, 12.37.

Photoreaction of **1b** with **2f**. 1-Methyl-3-(2-thienyl)quinolinone **3f**.

A solution of **1b** (0.700 g, 3 mmoles) and thiophene **2f** (20 ml) in acetonitrile (200 ml) and acetone (100 ml) was irradiated for 48 hours as mentioned above. After the removal of the solvent under reduced pressure, the residue was chromatographed on a silica gel column with ethyl acetate-petroleum ether (1:2) elution to give **3f** (17%), mp 108-110°; ir (potassium bromide): 1630 and 1580

cm^{-1}; ^{1}H-nmr (deuteriochloroform): δ 3.85 (s, 3H, *N*-methyl protons), 7.10 (m, 2H, thiophene β-protons), 7.20-7.90 (m, 4H, aromatic protons), 7.35 (broad s, 1H, thiophene α-H), 8.15 (m, 1H, quinolinone 4-H); ms: m/e 241 (M^+), 236, 232, 224, 217, 212; uv (acetonitrile): λ max 241.9 nm (ε 8.07 x 10^3); fluorescence maximum (acetonitrile): 425.0 nm (excitation at 242 nm).

Anal. Calcd. for $C_{14}H_{11}NOS$: C, 69.68; H, 4.59; N, 5.80. Found: C, 69.52; H, 4.43; N, 5.82.

Photoreaction of **1b** with **2g**. 3-(2-Furyl)-1-methylquinolinone **3g**.

A solution of **1b** (1.140 g, 5 mmoles) and furan **2g** (25 ml) in acetonitrile (300 ml) was irradiated for 24 hours as mentioned above. After the removal of the solvent under reduced pressure, the residue was chromatographed on a silica gel column with ethyl acetate-petroleum ether (1:4) elution to give **3g** (38%), mp 98-101°; ir (potassium bromide): 1645 and 1598 cm^{-1}; ^{1}H-nmr (deuteriochloroform): δ 3.85 (s, 3H, *N*-methyl protons), 6.70 (m, 2H, furan β-protons), 7.35-7.70 (m, 5H, aromatic protons), 8.20 (m, 1H, furan α-H); ms: m/e 225 (M^+), 196, 182, 167, 149, 137; uv (acetonitrile): λ max 239.9 nm (ε 1.78 x 10^4); fluorescence maximum (acetonitrile): 408.8 nm (excitation at 240 nm).

Anal. Calcd. for $C_{14}H_{11}NO_2$: C, 74.67; H, 4.89; N, 6.22. Found: C, 74.30; H, 4.84; N, 6.29.

X-ray Crystallographic Analysis of **4**.

Colorless crystals of **4** were obtained by recrystallization from 95% ethanol. The crystal structure was determined on an ENRAF-NONIUS CAD 4 diffractometer with graphite monochromatized Mo Kα radiation (λ = 0.71073 Å). A total of 3280 reflections were collected of which 750 were unique. Unique reflections of 750 were collected in the range of $2° < \theta < 25°$ using $\omega - 2\theta$ scan technique. The intensities of the reflections were reduced to the amplitudes of structure factors and LP correction and absorption correction were applied. The structure was solved with a direct method (MULTAN 82). Most of non-hydrogen atoms were found in the succeeding difference Fourier syntheses. The coordinates of hydrogen atoms were calculated. In the final structure refinement by the full matrix least-square method, the anisotropic thermal parameters and coordinates of non-hydrogen atoms and the isothermal parameters of hydrogen atoms were refined. The final R factors are R = 0.082 and R_w = 0.088. The maximum residual electron density peak on the final difference Fourier map is 0.24 e/Å^3.

The crystal data were the followings: $C_{22}H_{17}NO$, M = 311.39, monoclinic, space group Ic, a = 25.830(5), b = 5.661(1), c = 25.479(6) Å, β = 117.65(2)°, V = 3300.2 Å^3, Z = 8, Dc = 1.253 g/cm^3. The final atomic coordinates for non-hydrogen atoms, bond lengths and bond angles are tabulated (Tables 2-4).

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