Alpha Vinylation of Haloquinoline-5,8-diones with Methyl Acrylate and Methyl Vinyl Ketone under Baylis-Hillman Reaction Conditions

Hyoung Seok Song, Young Seok Song and Kee-Jung Lee*

Organic Synthesis Laboratory, Department of Chemical Engineering
Hanyang University, Seoul 133-791, Korea
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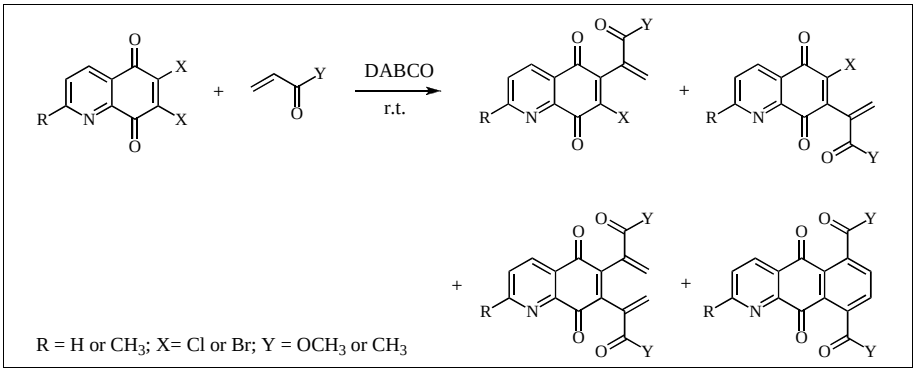

A synthesis of mono- and di-vinylquinolinediones based on substitution of the halogens in 6,7-dihaloquinoline-5,8-diones by DABCO-assisted enolate ion is described. Divinylquinolines undergo 6π-electrocyclization by thermally to give the benzo[*g*]quinoline derivatives.

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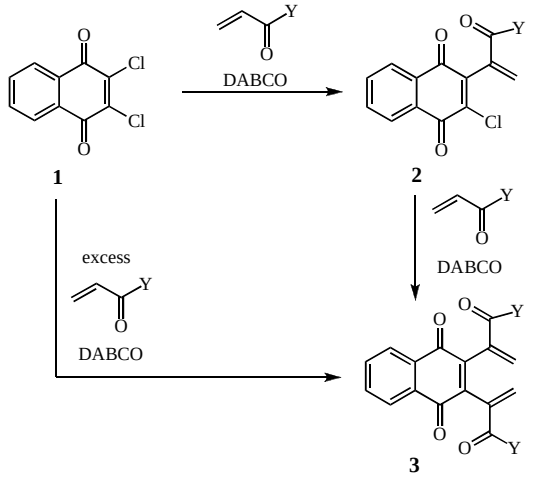
Quinoline-5,8-diones have wide spectra of biological activities such as antitumor, antibacterial, antifungal and antimalarial agents [1-10]. The syntheses and the biological activities of 6,7-functionalized quinoline-5,8-diones such as amino, hydroxy, methoxy, thiol and halogen have been reported [1-4,11-17].

The Baylis-Hillman reaction has been one of the most intensively studied carbon-carbon bond-forming reactions in organic synthesis [18]. In our earlier paper [19], we demonstrated that 1,4-diazabicyclo[2,2,2]octane (DABCO)-assisted enolate anion of activated olefins were useful in substitution reactions of 2,3-dihalo-1,4-naphthoquinones leading to the formation of the α-vinylnaphthoquinones under Baylis-Hillman reaction conditions as shown in Scheme I. We desired to extend this method to haloquinoline-5,8-dione derivatives. Typical methods for introducing α-vinyl unit into substrates involve palladium-catalyzed cross-coupling reactions of α-stannyl acrylate with aryl iodides or triflates [20], ethyl 2-bromoacrylate with arylboronic acids [21] and ethyl 2-bromoarylate with aryl halides using electro-generated reactive zinc metal [22].

Scheme I

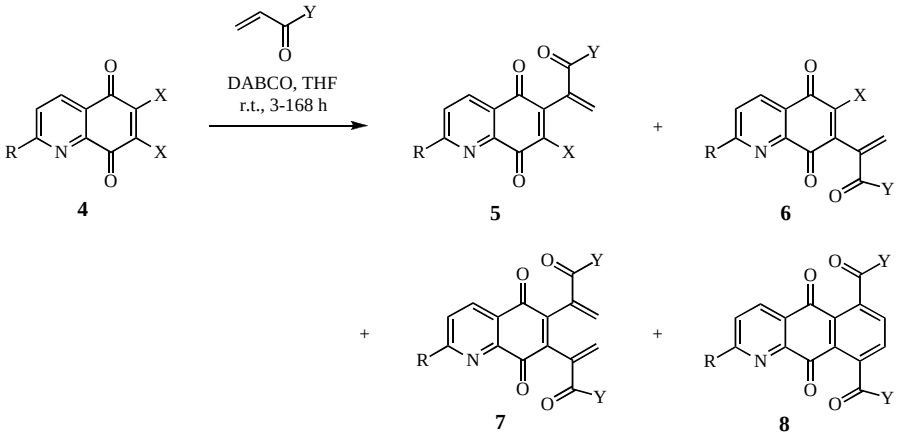


First, treatment of 6,7-dichloroquinoline-5,8-dione (**4a**) with methyl acrylate (3 equivalents) and DABCO (1.2 equivalents) in tetrahydrofuran was stirred at room temperature for 48 hours, two regioisomeric vinylquinolinediones **5a** and **6a** could be isolated by column chromatography in 15 and 59% yields in the order of elution (Table 1, Entry 1) [23] (Scheme II). When the reaction was conducted using excess methyl acrylate (6 equivalents) and DABCO (2.5 equivalents) at room temperature for 5 hours vinylquinolinediones **5a** (14%), **6a** (42%) and divinylquinolinedione **7a** (12%) were obtained (Entry 2), and for the prolonged reaction times of 7 days, **7a** (52%) was given exclusively (Entry 3). However, reaction of **4a** with methyl vinyl ketone (3 equivalents) and DABCO (1.2 equivalents) in tetrahydrofuran at room temperature for 48 hours afforded vinylquinolines **5b** (27%), **6b** (21%) [23], divinylquinolinedione **7b** (5%) and 6,9-diacetylbenzo[*g*]quinoline-5,10-dione **8b** (2%) (Entry 4). In order to increase the yields of divinyl compound **7b** or benzoquinolinedione

8b, **4a** was treated with excess methyl vinyl ketone (6 equivalents) and DABCO (2.5 equivalents) for 48 hours, however, disappointing yields of **7b** (12%) and **8b** (3%) were isolated [24] (Entry 5). The yields could be slightly improved by shortening the reaction time. Thus, after 3 hours, we could isolate compounds **5b** (19%), **6b** (13%), **7b** (9%) and **8b** (1%) (Entry 6) and after 24 hours, **7b** (18%) and **8b** (2%) were obtained [24] (Entry 7).

linediones **5c** (12%), **6c** (24%) together with recovered starting quinolinedione **4b** (25%) were given (Entry 8). Using excess methyl acrylate (6 equivalents) and DABCO (2.5 equivalents) vinylquinolinediones **5c** (17%), **6c** (37%) and divinylquinolinediones **7c** (4%) were obtained (Entry 9) [25]. Using 0.5 equivalents of DABCO **5c** (9%), **6c** (18%) and recovered starting quinolinedione **4b** (46%) were given (Entry 10). Similar reactions of **4b** with methyl

Scheme II



4	R	X	**5-8**	R	X	Y
a	H	Cl	**a**	H	Cl	OMe
b	Me	Br	**b**	H	Cl	Me
			c	Me	Br	OMe
			d	Me	Br	Me

When the reaction of 6,7-dibromo-2-methylquinoline-5,8-dione (**4b**) with methyl acrylate (3 equivalents) and DABCO (1.2 equivalents) was conducted in tetrahydrofuran for 48 hours, the expected regioisomeric vinylquinovinyl ketone and DABCO gave comparable results as shown in Table 1 (Entries 11-13).

Also, we studied these vinylation reactions of 6-bromo- and 7-bromo-2-methylquinoline-5,8-diones **9** and **10** with

Table 1

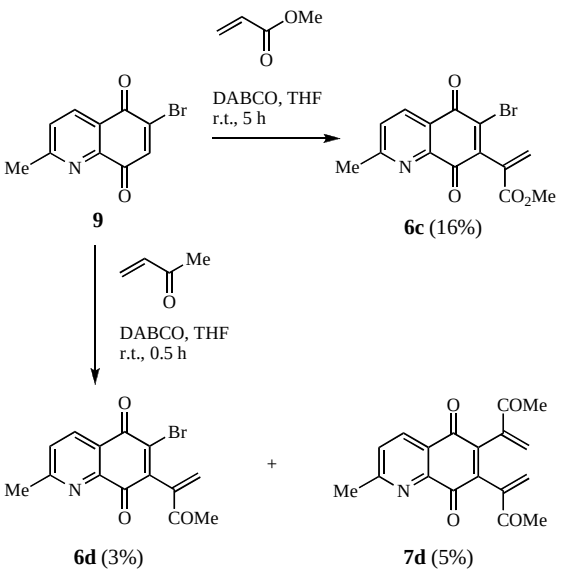
Reaction of 6,7-Dihaloquinoline-5,8-diones **4** with Methyl Acrylate and Methyl Vinyl Ketone

Entry	Reactant	Reaction Condition [a]	Time (h) [b]	Product (% yield)			
1	**4a**	MA/DABCO (3/1.2)	48	**5a** (15)	**6a** (59)		
2	**4a**	MA/DABCO (6/2.5)	5	**5a** (14)	**6a** (42)	**7a** (12)	
3	**4a**	MA/DABCO (6/2.5)	168			**7a** (52)	
4	**4a**	MVK/DABCO (3/1.2)	48	**5b**(27)	**6b** (21)	**7b** (5)	**8b** (2)
5	**4a**	MVK/DABCO (6/2.5)	48			**7b** (12)	**8b** (3)
6	**4a**	MVK/DABCO (6/2.5)	3	**5b** (19)	**6b** (13)	**7b** (9)	**8b** (1)
7	**4a**	MVK/DABCO (6/2.5)	24			**7b** (18)	**8b** (2)
8	**4b**	MA/DABCO (3/1.2)	48	**5c** (12)	**6c** (24)	**4b** (25)	
9	**4b**	MA/DABCO (6/2.5)	5	**5c** (17)	**6c** (37)	**7c** (4)	
10	**4b**	MA/DABCO (3/0.5)	48	**5c** (9)	**6c** (18)	**4b** (46)	
11	**4b**	MVK/DABCO (3/1.2)	48	**5d** (30)	**6d** (18)	**4b** (14)	
12	**4b**	MVK/DABCO (6/2.5)	3	**5d** (31)	**6d** (22)	**7d** (5)	**8d** (1)
13	**4b**	MVK/DABCO (3/0.5)	48	**5d** (19)	**6d** (10)	**4b** (35)	

[a] MA = methyl acrylate; MVK = methyl vinyl ketone. Parentheses values are the number of equivalents based on one equivalent of **4**. [b] Room temperature.

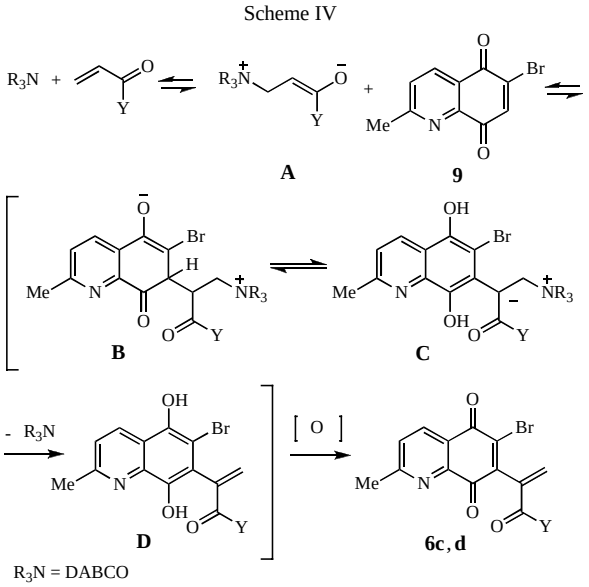
methyl acrylate and methyl vinyl ketone. Although the yields are very low, in the case of 6-bromo-2-methylquinoline-5,8-dione (**9**), vinylation with methyl acrylate proceeded exclusively at the carbon bearing hydrogen to afford the 6-bromo-2-methyl-7-vinylquinoline-5,8-dione **6c** (16%) and vinylation with methyl vinyl ketone to give the corresponding vinylquinolinedione **6d** (3%) and divinylquinolinedione **7d** (5%) as shown in Scheme III. Reason of the

Scheme III



low yields might be attributed to the side reactions that bromoquionlinedione **9** could react with the DABCO without methyl acrylate or methyl vinyl ketone presumably to give unidentified DABCO salt very rapidly indicated by thin layer chromatography. A plausible mechanism of the reaction as shown in Scheme IV is that the zwitterionic

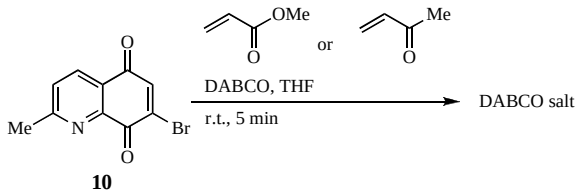
Scheme IV



enolate ion **A** makes a nucleophilic attack at the carbon bearing hydrogen of the 6-bromo-2-methylquinoline-5,8-dione (**9**) to generate the zwitterionic intermediate **B**. A subsequent proton migration by enol-keto tautomerization and extrusion of DABCO followed by oxidation affords 7-vinylquinoline-5,8-diones **6c** or **6d**.

Presumably the bulkiness of bromine makes the *ipso*-attack difficult, thus it makes the attack at the C7 position favorable [11a]. However, in the case of 7-bromoquinolinedione **10**, no vinylation product was observed. Again, DABCO salt compound was formed immediately (Scheme V). At this stage, we could determine the structures of two regioisomeric vinylquinoinedione

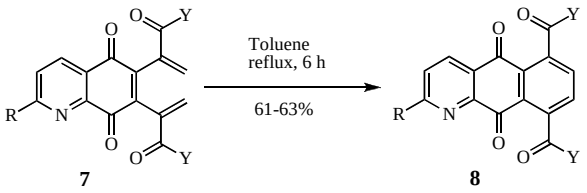
Scheme V



derivatives **5c**/**6c** and **5d**/**6d** comparing with above results.

Finally, we could prepare the 6,9-disubstituted benzo[*g*]quinolines **8** by 6π-electrocyclization of divinyl compounds **7** in refluxing toluene in moderate yields (61-63%) *via* the oxidation of the intermediate at reaction conditions, spontaneously (Scheme VI).

Scheme VI



For R and Y see Scheme II

In conclusion, additional examples of the use of DABCO-assisted enolate anion of methyl acrylate and methyl vinyl ketone in substitution reactions of haloquinolinediones to form α-vinylquinolinedione and α-divinylquinolinedione bonds avoiding the use of organometallic reagents has been descried. The divinylquinolinediones are converted to benzo[*g*]quinoline derivatives readily.

EXPERIMENTAL

All reagents and solvents were reagent grade or were purified by standard methods before use. Silica gel 60 (80-230 mesh ASTM) used for column chromatography was supplied by E. Merck.

Analytical thin layer chromatography (tlc) was carried out on Merck silica gel 60 F254 tlc plates. Melting points were taken using an Electrothermal melting point apparatus and are uncorrected. Microanalyses were obtained using a Carlo Erba EA 1180 element analyzer. Infrared spectra were recorded on a Nicolet Magna 550 FTIR spectrometer. The ^{1}H and ^{13}C NMR spectra were measured on a Gemini 300 spectrometer. All chemical shifts are reported in parts per million (δ) relative to tetramethylsilane and coupling constants (J) are expressed in Hertz.

The 6,7-dichloroquinoline-5,8-dione (**4a**) [6], 6,7-dibromo-2-methylquinoine-5,8-dione (**4b**) [26], 6-bromo-2-methylquinoline-5,8-dione (**9**) [11a], and 7-bromo-2-methylquionine-5,8-dione (**10**) [11a] were prepared following the literature procedures.

Methyl 2-(7-Chloro-5,8-dihydro-5,8-dioxoquinolin-6-yl)propenoate (**5a**) and Methyl 2-(6-Chloro-5,8-dihydro-5,8-dioxoquinolin-7-yl)propenoate (**6a**).

Typical Procedure.

To a stirred solution of 6,7-dichloroquinoline-5,8-dione (**4a**) (0.45 g, 2 mmoles) in tetrahydrofuran (10 ml) was added methyl acrylate (0.54 ml, 6 mmoles) and DABCO (0.27 g, 2.4 mmoles) at room temperature. After stirring at the same temperature for 48 hours the reaction mixture was diluted with water (20 ml) and extracted with dichloromethane (3 × 50 ml). The combined organic layers were dried over anhydrous magnesium sulfate and the solvent was evaporated *in vacuo*. The resulting mixture was chromatographed on silica gel eluting with hexane/ethyl acetate (4:1) to afford 0.08 g (15%) of **5a** and 0.32 g (59%) of **6a** in the order of elution.

5a: Orange solid; mp 147-148.5°C; ir (potassium bromide): 1738, 1688, 1660, 1575 cm^{-1}; ^{1}H nmr (deuteriochloroform): δ 3.80 (s, 3H), 5.99 (s, 1H), 6.88 (s, 1H), 7.75 (dd, 1H, J = 7.9 and 4.9 Hz), 8.48 (dd, 1H, J = 7.9 and 1.8 Hz), 9.10 (dd, 1H, J = 4.9 and 1.8 Hz); ^{13}C nmr (deuteriochloroform): δ 52.7, 128.2, 128.7, 131.7, 132.4, 133.2, 135.3, 144.6, 147.0, 155.1, 164.3, 176.0, 180.7.

Anal. Calcd. for $C_{13}H_8ClNO_4$: C, 56.23; H, 2.90; N, 5.04. Found: C, 56.09; H, 2.78; N, 4.85.

6a: Yellow solid; mp 142-143.5°C; ir (potassium bromide): 1735, 1676, 1633, 1579 cm^{-1}; ^{1}H nmr (deuteriochloroform); δ 3.79 (s, 3H), 6.00 (s, 1H), 6.90 (s, 1H), 7.55 (dd, 1H, J = 7.9 and 4.6 Hz), 8.55 (dd, 1H, J = 7.9 and 1.8 Hz), 9.11 (dd, 1H, J = 4.6 and 1.8 Hz); ^{13}C nmr (deuteriochloroform): δ 52.6, 127.9, 128.4, 132.4, 133.2, 135.2, 143.3, 143.6, 147.0, 155.3, 164.2, 177.3, 179.4.

Anal. Calcd. for $C_{13}H_8ClNO_4$: C, 56.23; H, 2.90; N, 5.04. Found: C, 56.05; H, 2.83; N,4.90.

6,7-Di-(1-carbomethoxyethen-1-yl)quinoline-5,8-dione (**7a**).

A mixture of **4a** (0.45 g, 2 mmoles), methyl acrylate (1.08 ml, 12 mmoles) and DABCO (0.56 g, 5 mmoles) in tetrahydrofuran (10 ml) was stirred for 7 days at room temperature. The work-up procedure was the same as described above to afford 0.34 g (52%) of **7a** as an orange solid; mp 124-125°C; ir (potassium bromide): 1737, 1727, 1676, 1665, 1579, 1435 cm^{-1}; ^{1}H nmr (deuteriochloroform): δ 3.76 (s, 3H), 3.78 (s, 3H), 5.79 (s, 2H), 6.61 (s, 1H), 6.62 (s, 1H), 7.73 (dd, 1H, J = 7.9 and 4.6 Hz), 8.47 (dd, 1H, J = 7.9 and 1.8 Hz), 9.08 (dd, 1H, J = 4.6 and 1.8 Hz); ^{13}C nmr (deuteriochloroform): δ 52.4, 52.5, 127.8, 128.8, 131.3, 131.5, 134.1, 134.7, 134.8, 142.9, 144.1, 147.2, 154.9, 164.9, 165.0, 181.7, 183.1.

Anal. Calcd. for $C_{17}H_{13}NO_6$: C, 62.39; H, 4.00; N, 4.28. Found: C, 62.21; H, 3.88; N, 4.16.

3-(7-Chloro-5,8-dihydro-5,8-dioxoquinolin-6-yl)-3-buten-2-one (**5b**), 3-(6-Chloro-5,8-dihydro-5,8-dioxoquinolin-7-yl)-3-buten-2-one (**6b**), 6,7-Di-(3-buten-2-on-3-yl)quinoline-5,8-dione (**7b**) and 6,9-Diacetylbenzo[*g*]quinoline-5,10-dione (**8b**).

Typical Procedure.

To a stirred solution of **4a** (0.45 g, 2 mmoles) in tetrahydrofuran (10 ml) was added methyl vinyl ketone (0.50 ml, 6 mmoles) and DABCO (0.27 g, 2.4 mmoles) at room temperature. After stirring at the same temperature for 48 hours the reaction mixture was diluted with water (20 ml) and extracted with dichloromethane (3 × 50 ml). The combined organic layers were dried over anhydrous magnesium sulfate and the solvent was evaporated *in vacuo*. The resulting mixture was chromatographed on silica gel eluting with hexane / ethyl acetate (2:1) to afford 0.14 g (27%) of **5b**, 0.11 g (21%) of **6b**, 0.03 g (5%) of **7b** and 0.01 g (2%) of **8b**.

5b: Yellow solid; mp 141-143°C; ir (potassium bromide): 1692, 1680, 1664, 1598, 1579 cm^{-1}; ^{1}H nmr (deuteriochloroform); δ 2.52 (s, 3H), 6.17 (s, 1H), 6.65 (s, 1H), 7.74 (dd, 1H, J = 7.9 and 4.6 Hz), 8.45 (dd, 1H, J = 7.9 and 1.8 Hz), 9.09 (dd, 1H, J = 4.6 and 1.8 Hz); ^{13}C nmr (deuteriochloroform): δ 25.6, 128.1, 128.7, 131.2, 135.2, 141.3, 143.9, 144.5, 146.9, 154.9, 175.8, 180.6, 196.2.

Anal. Calcd. for $C_{13}H_8ClNO_3$: C, 59.67; H, 3.08; N, 5.35. Found: C, 59.50; H, 2.89; N, 5.27.

6b: Oil; ir (potassium bromide): 1687, 1676, 1598, 1579 cm^{-1}; ^{1}H nmr (deuteriochloroform); δ 2.52 (s, 3H), 6.14 (s, 1H), 6.64 (s, 1H), 7.74 (dd, 1H, J = 7.9 and 4.9 Hz), 8.53 (dd, 1H, J = 7.9 and 1.8 Hz), 9.09 (dd, 1H, J = 4.9 and 1.8 Hz); ^{13}C nmr (deuteriochloroform): δ 25.6, 127.8, 128.2, 131.1, 135.0, 141.1, 143.3, 144.7, 146.8, 155.0, 176.9, 179.2, 196.0.

Anal. Calcd. for $C_{13}H_8ClNO_3$: C, 59.67; H, 3.08; N, 5.35. Found: C, 59.53; H, 3.27; N, 5.18.

7b: Brown solid; mp 147-148°C; ir (potassium bromide): 1672, 1656, 1596, 1577 cm^{-1}; ^{1}H nmr (deuteriochloroform); δ 2.46 (s, 3H), 2.47 (s, 3H), 5.89 (s, 1H), 5.93 (s, 1H), 6.27 (s, 1H), 6.28 (s, 1H), 7.70 (dd, 1H, J = 7.9 and 4.9 Hz), 8.41 (dd, 1H, J = 7.9 and 1.8 Hz), 9.05 (dd, 1H, J = 4.9 and 1.8 Hz); ^{13}C nmr (deuteriochloroform): δ 25.7, 25.8, 127.6, 127.9, 128.5, 128.9, 134.5, 134.8, 143.3, 144.9, 146.1, 147.2, 154.8, 181.5, 182.9, 197.8 (two).

Anal. Calcd. for $C_{17}H_{13}NO_4$: C, 69.15; H, 4.44; N, 4.74. Found: C, 69.02; H, 4.37; N, 4.58.

8b: Yellow solid; mp 260-261°C; ir (potassium bromide): 1703, 1680, 1579 cm^{-1}; ^{1}H nmr (deuteriochloroform); δ 2.60 (s, 3H), 2.61 (s, 3H), 7.643 (s, 1H), 7.647 (s, 1H), 7.81 (dd, 1H, J = 7.9 and 4.6 Hz), 8.60 (dd, 1H, J = 7.9 and 1.5 Hz), 9.16 (dd, 1H, J = 4.6 and 1.5 Hz); ^{13}C nmr (deuteriochloroform): δ 30.7, 30.8, 128.7, 129..9, 130.3, 130.9, 131.4, 131.6, 135.2, 144.3, 144.5, 148.5, 155.2, 181.2, 182.9, 203.4, 203.5.

Anal. Calcd. for $C_{17}H_{11}NO_4$: C, 69.62; H, 3.78; N, 4.78. Found: C, 69.40; H, 3.66; N, 4.63.

Methyl 2-(7-Bromo-5,8-dihydro-5,8-dioxo-2-methylquinolin-6-yl)propenoate (**5c**) and Methyl 2-(6-Bromo-5,8-dihydro-5,8-dioxo-2-methylquinolin-7-yl)propenoate (**6c**).

Method A.

A mixture of **4b** (0.66 g, 2 mmoles), methyl acrylate (0.54 ml, 6 mmoles) and DABCO (0.27 g, 2.4 mmoles) in tetrahydrofuran

(10 ml) was stirred for 48 hours at room temperature. The work-up procedure was the same as described above to give 0.16 g (25%) of recovered starting quinolinedione **4b**, 0.08 g (12%) of **5c** and 0.16 g (24%) of **6c**.

5c: Brown solid; mp 116-118°C; ir (potassium bromide): 1719, 1680, 1661, 1590, 1571 cm^{-1}; ^1H nmr (deuteriochloroform); δ 2.80 (s, 3H), 3.79 (s, 3H), 5.96 (s, 1H), 6.84 (s, 1H), 7.58 (d, 1H, J = 8.3 Hz), 8.33 (d, 1H, J = 8.3 Hz); ^{13}C nmr (deuteriochloroform): δ 25.3, 52.6, 126.5, 128.1, 132.6, 134.6, 135.4, 139.9, 145.9, 146.2, 164.1, 165.5, 176.2, 180.4.

Anal. Calcd. for $C_{14}H_{10}BrNO_4$: C, 50.02; H, 3.00; N, 4.17. Found: C, 49.87; H, 2.91; N, 4.03.

6c: Yellow solid; mp 133.5-134.5°C; ir (potassium bromide): 1734, 1676, 1579 cm^{-1}; ^1H nmr (deuteriochloroform); δ 2.80 (s, 3H), 3.77 (s, 3H), 5.95 (s, 1H), 6.84 (s, 1H), 7.57 (d, 1H, J = 7.9 Hz), 8.41 (d, 1H, J = 7.9 Hz); ^{13}C nmr (deuteriochloroform): δ 25.3, 52.6, 126.1, 127.9, 132.7, 134.7, 135.6, 138.7, 146.5, 146.9, 164.0, 165.8, 177.3, 189.2.

Anal. Calcd. for $C_{14}H_{10}BrNO_4$: C, 50.02; H, 3.00; N, 4.17. Found: C, 49.76; H, 2.88; N, 3.92.

Method B.

A mixture of **4b** (0.66 g, 2 mmoles), methyl acrylate (0.54 ml, 6 mmoles) and DABCO (0.06 g, 0.5 mmoles) in tetrahydrofuran (10 ml) was stirred for 48 hours at room temperature. The work-up procedure was the same as described above to give 0.30 g (46%) of recovered starting quinolinedione **4b**, 0.06 g (9%) of **5c** and 0.12 g (18%) of **6c**.

Methyl 2-(7-Bromo-5,8-dihydro-5,8-dioxo-2-methylquinolin-6-yl)propenoate (**5c**), Methyl 2-(6-Bromo-5,8-dihydro-5,8-dioxo-2-methylquinolin-7-yl)propenoate (**6c**) and 6,7-Di-(1-carbomethoxyethen-1-yl)-2-methylquinoline-5,8-dione (**7c**).

A mixture of **4b** (0.66 g, 2 mmoles), methyl acrylate (1.08 ml, 12 mmoles) and DABCO (0.56 g, 5 mmoles) in tetrahydrofuran (10 ml) was stirred for 5 hours at room temperature. The work-up procedure was the same as described above to give 0.11 g (17%) of **5c**, 0.25 g (37%) of **6c** and 0.03 g (4%) of **7c**.

7c: Oil; ^1H nmr (deuteriochloroform); δ 2.82 (s, 3H), 3.75 (s, 3H), 3.77 (s, 3H), 5.77 (s, 1H), 5.78 (s, 1H), 6.59 (s, 1H), 6.60 (s, 1H), 7.56 (d, 1H, J = 7.9 Hz), 8.33 (d, 1H, J = 7.9 Hz); ^{13}C nmr (deuteriochloroform): δ 25.2, 52.4, 52.5, 126.7, 127.8, 128.4, 128.5, 131.2, 131.4, 134.2, 134.8, 142.6, 143.8, 146.7, 165.1, 165.4, 182.0, 183.1.

Anal. Calcd. for $C_{18}H_{15}NO_6$: C, 63.34; H, 4.43; N, 4.10. Found: C, 63.22; H, 4.31; N, 4.25.

3-(7-Bromo-5,8-dihydro-5,8-dioxo-2-methylquinolin-6-yl)-3-buten-2one (**5d**) and 3-(6-Bromo-5,8-dihydro-5,8-dioxo-2-methylquinolin-7-yl)-3-buten-2-one (**6d**).

Method A.

A mixture of **4b** (0.66 g, 2 mmoles), methyl vinyl ketone (0.50 ml, 6 mmoles) and DABCO (0.27 g, 2.4 mmoles) in tetrahydrofuran (10 ml) was stirred for 48 hours at room temperature. The work-up procedure was the same as described above to give 0.09 g (14%) of recovered starting quinolinedione **4b**, 0.19 g (30%) of **5d** and 0.12 g (18%) of **6d**.

5d: Yellow solid; mp 111-112°C; ir (potassium bromide): 1692, 1672, 1653, 1598, 1575 cm^{-1}; ^1H nmr (deuteriochloroform); δ 2.50 (s, 3H), 2.79 (s, 3H), 6.13 (s, 1H), 6.61 (s, 1H), 7.57 (d, 1H, J = 7.9 Hz), 8.28 (d, 1H, J = 7.9 Hz); ^{13}C nmr (deuteriochloroform): δ 25.0, 25.6, 126.3, 127.9, 130.7, 135.1, 139.5, 143.2, 145.9, 147.2, 165.2, 175.8, 180.0, 195.9.

Anal. Calcd. for $C_{14}H_{10}BrNO_3$: C, 52.52; H, 3.15; N, 4.38. Found: C, 52.39; H, 3.02; N, 4.50.

6d: Brown solid; mp 104-105°C; ir (potassium bromide): 1684, 1680, 1663, 1598, 1575 cm^{-1}; ^1H nmr (deuteriochloroform); δ 2.50 (s, 3H), 2.78 (s, 3H), 6.10 (s, 1H), 6.59 (s, 1H), 7.55 (d, 1H, J = 7.9 Hz), 8.38 (d, 1H, J = 7.9 Hz); ^{13}C nmr (deuteriochloroform): δ 25.2, 25.7, 126.0, 127.8, 130.4, 135.4, 138.7, 143.4, 146.4, 148.2, 165.6, 177.0, 179.0, 195.8.

Anal. Calcd. for $C_{14}H_{10}BrNO_3$: C, 52.52; H, 3.15; N, 4.38. Found: C, 52.31; H, 2.98; N, 4.22.

Method B.

A mixture of **4b** (0.66 g, 2 mmoles), methyl vinyl ketone (0.50 ml, 6 mmoles) and DABCO (0.06 g, 0.5 mmoles) in tetrahydrofuran (10 ml) was stirred for 48 hours at room temperature. The work-up procedure was the same as described above to give 0.23 g (35%) of recovered starting quinolinedione **4b**, 0.12 g (19%) of **5d** and 0.06 g (10%) of **6d**.

3-(7-Bromo-5,8-dihydro-5,8-dioxo-2-methylquinolin-6-yl)-3-buten-2-one (**5d**), 3-(6-Bromo-5,8-dihydro-5,8-dioxo-2-methylquinolin-7-yl)-3-buten-2-one (**6d**), 6,7-Di-(3-buten-2-on-3-yl)-2-methylquinoline-5,8-dione (**7d**) and 6,9-Diacetyl-2-methylbenzo[*g*]quinoline-5,10-dione (**8d**).

A mixture of **4b** (0.66 g, 2 mmoles), methyl vinyl ketone (1.0 ml, 12 mmoles) and DABCO (0.56 g, 5 mmoles) in tetrahydrofuran (10 ml) was stirred for 3 hours at room temperature. The work-up procedure was the same as described above to give 0.20 g (30%) of **5d**, 0.14 g (22%) of **6d**, 0.03 g (5%) of **7d** and 61 mg (1%) of **8d**.

7d: Dark brown solid; mp 144-146°C; ir (potassium bromide): 1684, 1672, 1657, 1587 cm^{-1}; ^1H nmr (deuteriochloroform); δ 2.45 (s, 6H), 2.76 (s, 3H), 5.86 (s, 1H), 5.92 (s, 1H), 6.24 (s, 1H), 6.27 (s, 1H), 7.53 (d, 1H, J = 7.9 Hz), 8.27 (d, 1H, J = 7.9 Hz); ^{13}C nmr (deuteriochloroform): δ 25.2, 25.8, 25.9, 126.7, 127.8, 128.1, 128.7, 134.8, 143.4, 143.5, 144.7, 145.8, 146.7, 165.2, 181.9, 183.0, 197.9 (two).

Anal. Calcd. for $C_{18}H_{15}NO_4$: C, 69.89; H, 4.89; N, 4.53. Found: C, 69.73; H, 4.75; N, 4.39.

8d: Ivory solid; mp 214.5-215.5°C; ir (potassium bromide): 1699, 1680, 1672, 1587 cm^{-1}; ^1H nmr (deuteriochloroform); δ 2.60 (s, 6H), 2.83 (s, 3H), 7.61 (s, 2H), 7.63 (d, 1H, J = 8.2 Hz), 8.46 (d, 1H, J = 8.2 Hz); ^{13}C nmr (deuteriochloroform): δ 25.4, 29.7, 30.7, 127.8, 128.7, 129.8, 130.4, 131.4, 131.6, 135.8, 145.1, 145.6, 147.6, 166.6, 181.2, 182.2, 202.9, 203.2.

Anal. Calcd. for $C_{18}H_{13}NO_4$: C, 70.35; H, 4.26; N, 4.56. Found: C, 70.20; H, 4.32; N, 4.28.

Reaction of 6-Bromo-2-methylquinoline-5,8-dione (**9**) with Methyl Acrylate. Synthesis of Methyl 2-(6-Bromo-5,8-dihydro-5,8-dioxo-2-methylquinolin-7-yl)propenoate (**6c**).

To a solution of **9** (0.50 g, 2 mmoles) in tetrahydrofuran (10 ml) was added methyl acrylate (0.54 ml, 6 mmoles) and DABCO (0.27 g, 2.4 mmoles), and the mixture was stirred for 5 hours at room temperature. The work-up procedure was the same as described above to give **6c** (0.11 g) in 16% yield.

Reaction of 6-Bromo-2-methylquinoline-5,8-dione (**9**) with Methyl Vinyl Ketone. Synthesis of 3-(6-Bromo-5,8-dihydro-5,8-dioxoquinolin-7-yl)-3-buten-2-one (**6d**) and 6,7-Di-(3-buten-2-on-3-yl)-2-methylquinline-5,8-dione (**7d**).

To a solution of **9** (0.50 g, 2 mmoles) in tetrahydrofuran (10 ml) was added methyl vinyl ketone (1.0 ml, 12 mmoles) and DABCO (0.56 g, 5 mmoles), and the mixture was stirred at room temperature for 0.5 hour. The work-up procedure was the same as described above to give **6d** (19 mg) and **7d** (32 mg) in 3 and 5% yield, respectively.

General Procedure for the Thermal Reaction of **7a-d**. Synthesis of Benzo[*g*]quinoline-5,10-diones **8a**-**d**.

A stirred solution of **7a-d** (1 mmole) in toluene (10 ml) was heated at reflux temperature for 6 hours and the solvent was evaporated *in vacuo*. The residue was chromatographed on silica gel eluting with hexane / ethyl acetate (2:1) to give **8a-d**.

6,9-Dicarbomethoxybenzo[*g*]quinoline-5,10-dione (**8a**).

Yield 63%; light yellow solid; mp 185-187°C; ir (potassium bromide): 1730, 1725, 1691, 1676 cm^{-1}; ^1H nmr (deuteriochloroform); δ 4.04 (s, 3H), 4.05 (s, 3H), 7.78 (dd, 1H, J = 7.9 and 4.6 Hz), 7.81 (s, 1H), 7.82 (s, 1H), 8.59 (dd, 1H, J = 7.9 and 1.8 Hz), 9.14 (dd, 1H, J = 4.6 and 1.8 Hz); ^{13}C nmr (deuteriochloroform): δ 53.2, 53.4, 128.3, 129.9, 130.2, 131.0, 132.7, 132.9, 135.5, 135.8, 136.3, 148.1, 155.6, 168.6, 168.7, 179.8, 181.1.

Anal. Calcd. for $C_{17}H_{11}NO_6$: C, 62.77; H, 3.41; N, 4.31. Found: C, 62.61; H, 3.20; N, 4.13.

6,9-Diacetylbenzo[*g*]quinoline-5,10-dione (**8b**).

Yield 62%; yellow solid; mp 260-261°C.

6,9-Dicarbomethoxy-2-methylbenzo[*g*]quinoline-5,0-dione (**8c**).

Yield 61%; light yellow solid; mp 177-178.5°C; ir (potassium bromide): 1731, 1719, 1684, 1672, 1590 cm^{-1}; ^1H nmr (deuteriochloroform); δ 2.82 (s, 3H), 4.05 (s, 6H), 7.62 (d, 1H, J = 8.2 Hz), 7.78 (s, 1H), 7.79 (s, 1H), 8.46 (d, 1H, J = 8.2 Hz); ^{13}C nmr (deuteriochloroform): δ 25.5, 53.3, 53.4, 127.9, 128.5, 130.3, 131.0, 132.3, 132.9, 135.5, 135.8, 136.4, 147.7, 166.3, 168.8, 168.9, 180.1, 181.1.

Anal. Calcd. for $C_{18}H_{13}NO_6$: C, 63.72; H, 3.86; N, 4.13. Found: C, 63.59; H, 3.73; N, 3.90.

6,9-Diacetyl-2-methylbenzo[*g*]quinoline-5,10-dione (**8d**).

Yield 63%; ivory solid; mp 214-215°C.

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* Author to whom correspondence should be addressed.

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[23] The exact structures of regioisomers were not determined. The tentative structures of regioisomers **5a**/**6a** and **5b**/**6b** were determined by thin layer chromatography comparing with fully characterized **5c**/**6c** and **5d**/**6d**.

[24] No other distinct spots including starting quinolinedione **4a** were observed by thin layer chromatography.

[25] When employing 6 equivalents of methyl acrylate and 2.5 equivalents of DABCO for 7 days, disappointing yields of **5c** (3%), **6c** (8%) and **7c** (7%) were obtained.

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