# Synthesis of Some Carbazolequinone Alkaloids and Their Analogues. Facile Palladium-Assisted Intramolecular Ring Closure of Arylamino-1,4-benzoquinones to Carbazole-1,4-quinones

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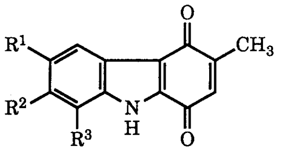
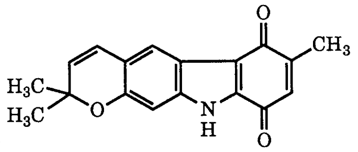
**Carbazolequinone alkaloids, murrayaquinone-A (1a), and pyrayaquinone-A (2) and -B (3), as well as pyrano[3,2-*b*]carbazolequinone 5, an isomer of 2 and 3, were prepared conveniently by the palladium-assisted intramolecular ring closure of the corresponding 2-arylamino-5-methyl-1,4-benzoquinones 9a and 9i—k. A series of their analogues, 6-, 7-, and 8-substituted 3-methylcarbazole-1,4-quinone derivatives 1b—g and 2-methylcarbazolequinones 6a—g corresponding to 1a—g, was also prepared in the same manner. Comparative analysis of the carbon-13 nuclear magnetic resonance spectra was found to provide useful information for the structural assignment of either 2- or 3-methylcarbazolequinones.**

**Keywords** carbazolequinone alkaloid; murrayaquinone-A; pyrayaquinone-A; pyrayaquinone-B; palladium(II) acetate; carbazole-1,4-quinone; arylamino-1,4-benzoquinone; $^{13}$C-NMR

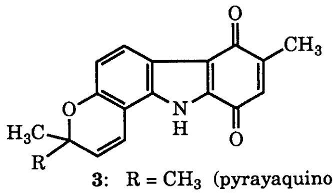
The carbazolequinone alkaloids murrayaquinones-A through -D (**1a** and **1h**—**j**) and pyrayaquinones-A through -C (**2**—**4**), having a 3-methylcarbazole-1,4-quinone skeleton, are characteristic constituents of *Murraya euchrestifolia* Hayata (Rutaceae).[1] Among these carbazolequinone alkaloids, murrayaquinone-A (**1a**) has been found to show a cardiotonic activity on guinea-pig papillary muscle.[2] Since their isolation, some synthetic studies of these alkaloids have been reported.[1a,b,3] However, most of these approaches do not allow easy access to various derivatives and thus there is still a need for a general and versatile synthetic procedure.



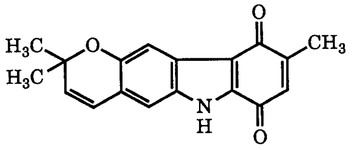
| | $R^1$ | $R^2$ | $R^3$ |
|---|---|---|---|
| **1a**: | H | H | H (murrayaquinone-A) |
| **1b**: | $CH_3$ | H | H |
| **1c**: | Cl | H | H |
| **1d**: | F | H | H |
| **1e**: | $OCH_3$ | H | H |
| **1f**: | H | $OCH_3$ | H |
| **1g**: | H | H | $OCH_3$ |
| **1h**: | H | $OCH_3$ | prenyl (murrayaquinone-B) |
| **1i**: | H | $OCH_3$ | geranyl (murrayaquinone-C) |
| **1j**: | H | OH | geranyl (murrayaquinone-D) |



**2** (pyrayaquinone-A)



**3**: R = $CH_3$ (pyrayaquinone-B)
**4**: R = $CH_2CH_2CH{=}C(CH_3)_2$ (pyrayaquinone-C)



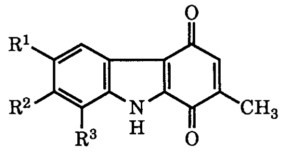
**5**

Recently, many palladium-assisted reactions have received considerable attention because of their versatile utilities in synthetic methodology.[4] For example, intramolecular cyclization of some diphenylamines by palladium(II) acetate [Pd(OAc)$_2$] is known to produce carbazole derivatives *via* a dehydrogenative coupling process.[5] The palladium-promoted oxidative coupling of 1,4-benzoquinone with aryl and heteroaryl compounds has been reported to give the corresponding aryl- and heteroaryl-1,4-benzoquinone derivatives, respectively.[6]

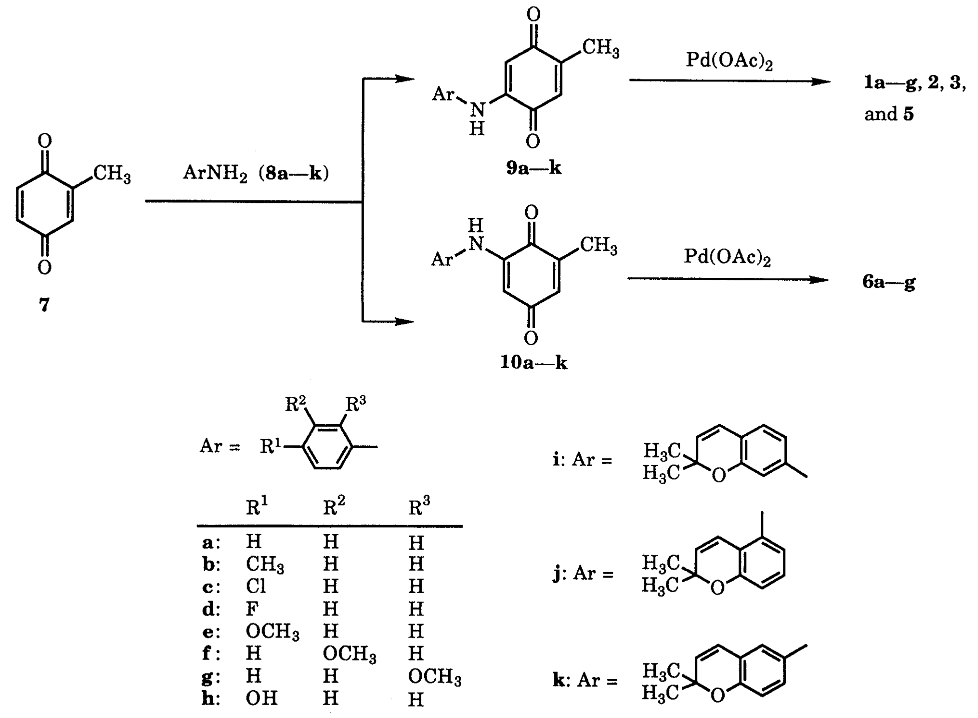
We have studied the palladium-assisted intramolecular ring closure of arylamino-1,4-benzoquinones as a facile alternative synthetic approach to carbazole-1,4-quinone derivatives. This paper describes the facile synthesis of the carbazolequinone alkaloids, murrayaquinone-A (**1a**), and pyrayaquinone-A (**2**) and -B (**3**), together with their analogues **1b**—**g**, **5**, and **6a**—**g**, which are of interest in connection with the biological activities of the parent compounds.[7]

## Results and Discussion

Treatment of 2-anilino-5-methyl-1,4-benzoquinone (**9a**),[8,9]



| | $R^1$ | $R^2$ | $R^3$ |
|---|---|---|---|
| **6a**: | H | H | H |
| **6b**: | $CH_3$ | H | H |
| **6c**: | Cl | H | H |
| **6d**: | F | H | H |
| **6e**: | $OCH_3$ | H | H |
| **6f**: | H | $OCH_3$ | H |
| **6g**: | H | H | $OCH_3$ |



| | $R^1$ | $R^2$ | $R^3$ |
|---|---|---|---|
| **a**: | H | H | H |
| **b**: | $CH_3$ | H | H |
| **c**: | Cl | H | H |
| **d**: | F | H | H |
| **e**: | $OCH_3$ | H | H |
| **f**: | H | $OCH_3$ | H |
| **g**: | H | H | $OCH_3$ |
| **h**: | OH | H | H |

Chart 1

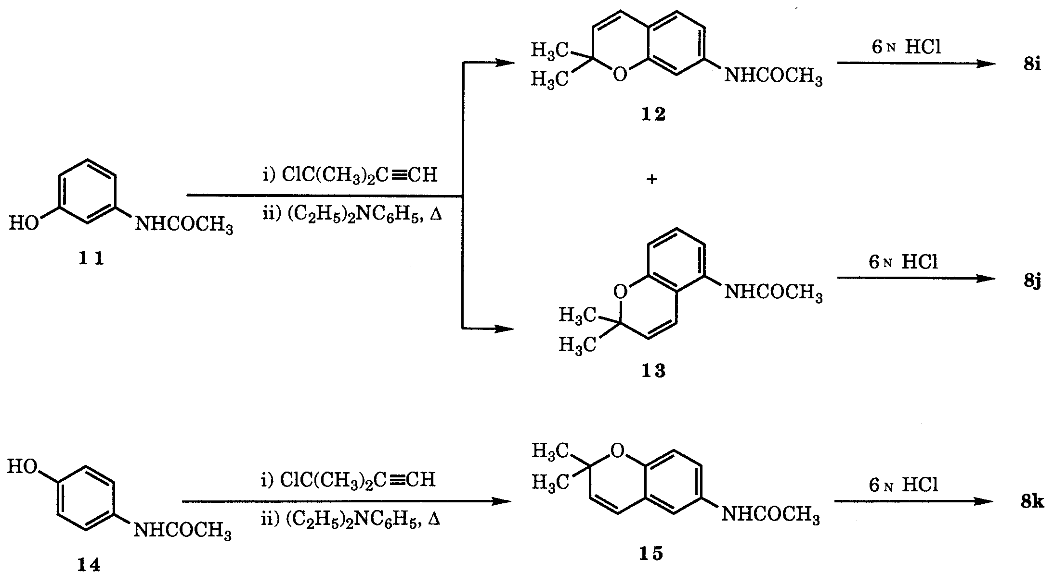


Chart 2

which was obtained together with 2-anilino-6-methyl-1,4-benzoquinone (**10a**) from methyl-1,4-benzoquinone (**7**) and aniline (**8a**),[10)] with an equimolar amount of Pd(OAc)$_2$ in acetic acid (AcOH) at reflux temperature for 50 min under an argon atmosphere afforded 3-methylcarbazole-1,4-quinone (**1a**) in 64% yield. This product was found to be identical with natural murrayaquinone-A[1a,b)] by spectrometric and co-thin layer chromatographic (TLC) comparisons. This synthetic method was then extended to the synthesis of pyrayaquinone-A (**2**) and -B (**3**).[1c)] The starting materials, 7-amino- (**8i**) and 5-amino-2,2-dimethyl-2*H*-chromene (**8j**), were concurrently produced from 3-acetamidophenol (**11**) and 3-chloro-3-methyl-1-butyne[11)] *via* etherification and a Claisen rearrangement followed by hydrolysis (Chart 2).[12)] Condensation[10)] of the aminochromenes **8i** and **8j** with the methylbenzoquinone **7** afforded 2-(2,2-dimethyl-2*H*-chromen-7-ylamino)- (**9i**) and 2-(2,2-dimethyl-2*H*-chromen-5-ylamino)-5-methyl-1,4-benzoquinone (**9j**) together with the corresponding 6-methyl isomers **10i** and **10j**, respectively.[13)] Distinction between them was readily accomplished by analysis of the signals due to the substituted methylbenzoquinone moiety in the proton nuclear magnetic resonance ($^1$H-NMR) spectra (see Experimental).[8)] Subsequent treatment of the benzoquinones **9i** and **9j** with Pd(OAc)$_2$ in AcOH under reflux for 4 min furnished 2,2,7-trimethyl-2*H*,10*H*-pyrano[2,3-*b*]carbazole-6,9-quinone (**2**) and 3,3,8-trimethyl-3*H*,11*H*-pyrano[3,2-*a*]carbazole-7,10-quinone (**3**) in 78 and 50% yields, respectively. The pyranocarbazolequinones **2** and **3** were shown to be identical with natural specimens of pyrayaquinone-A and -B, respectively.[1c)] Similarly, the linear pyrano[3,2-*b*]carbazolequinone **5**, which has a regioisomer of pyrayaquinone-A, was prepared from 4-acetamidophenol (**14**) by way of 6-acetamidochromene **15**,[12,14)] 6-aminochromene **8k**, and chromenylaminobenzoquinone **9k** as illustrated in Charts 2 and 1. The intramolecular cyclization of **9i** or **9k** gave the pyranocarbazolequinone **2** or **5**, respectively, as the sole isolated product, and no product cyclized in any other direction could be detected.

By means of the palladium-assisted intramolecular cyclization described above, benzenoid-ring-monosubstituted 3-methylcarbazole-1,4-quinone derivatives **1b**—**g** were obtained from 2-(substituted anilino)-5-methyl-1,4-benzoquinones **9b**—**g** in good yields. The cyclization of 6-methylated 2-anilino-1,4-benzoquinones **10a**—**g** with $Pd(OAc)_2$ also proceeded to furnish the corresponding 2-methylcarbazolequinones **6a**—**g** in good yields. In the cyclization of the 2-(3-methoxyanilino)benzoquinone **9f** or **10f**, the 7-methoxycarbazolequinone **1f** or **6f** was isolated as the sole product, respectively. Cyclization was not found to occur in any other direction.

Thus, the palladium-assisted intramolecular cyclization of the 5-methyl- and 6-methyl-2-arylamino-1,4-benzoquinones described here represents a useful synthetic method for 3-methyl- and 2-methylcarbazole-1,4-quinone derivatives. However, the present method can not be applied to the synthesis of the 5-substituted carbazolequinone derivatives in view of the results of the intramolecular cyclization of **9f**, **9i**, **9k**, and **10f** described above. Further, the reaction of anilinobenzoquinones **9h** and **10h** having a free hydroxy group resulted in the formation of a complex mixture, and attempts to isolate carbazolequinone derivatives were unsuccessful. Therefore, the protection of the hydroxy group is requisite for the synthesis of carbazolequinones bearing hydroxy groups.

During our structural elucidation of new carbazolequinones,[1a,b)] one of the problems was the assignment of the location of the methyl group (at C-2 or C-3) on the 1,4-quinone moiety. The chemical shift of the olefinic proton at H-3 or H-2 has been reported to be useful as an indicator.[1a,b)] In the $^1$H-NMR spectrum of the 2-methylcarbazolequinone **6a**, the resonance of the olefinic proton (H-3) appeared at lower field than that (H-2) of the corresponding 3-methyl compound **1a** as deduced in a previous report,[1b)] though the difference in chemical shift was small ($\Delta\delta_H$ 0.05 ppm). However, the olefinic proton signals of the 2-methyl derivatives **6b**—**e** appeared at rather higher field than those of the corresponding 3-methyl derivatives **1b**—**e**. These facts as well as comparison of the methyl proton resonances of **1a**—**g** with those of **6a**—**g** did not allow conclusive distinction between 2-methyl and 3-methyl derivatives on the basis of the $^1$H-NMR spectra.

In the present studies of the carbon-13 nuclear magnetic resonance ($^{13}$C-NMR) spectra, we found that **1a**—**g** showed the allyl methyl carbon signals at $\delta_C$ 15.3—15.7, whereas in **6a**—**g** they appeared at slightly higher field, at $\delta_C$ 14.8—15.0. Further, the olefinic tertiary carbon (C-2) resonances in **1a**—**g** were observed at $\delta_C$ 131.5—131.7, whereas the C-3 signals in **6a**—**g** appeared in the region of $\delta_C$ 134.1—134.9. Thus the chemical shift value of the allyl methyl carbon and that of the olefinic tertiary carbon[15)] may be used diagnostically for the determination of the location of the allyl methyl group in new carbazolequinone alkaloids.[16)]

TABLE I. $^1$H-NMR Data for the Olefinic Proton, and $^{13}$C-NMR Data for the Allyl Methyl and Olefinic Tertiary Carbons of **1a**—**g** and **6a**—**g**[a)]

| Compd. | $^1$H-NMR $\delta_H$ | | $^{13}$C-NMR $\delta_C$ | | |
|---|---|---|---|---|---|
| | H-2 | H-3 | $CH_3$ | C-2 | C-3 |
| **1a** | 6.50 | | 15.7 | 131.5 | |
| **1b** | 6.58 | | 15.5 | 131.5 | |
| **1c** | 6.63 | | 15.4 | 131.5 | |
| **1d** | 6.63 | | 15.4 | 131.6 | |
| **1e** | 6.58 | | 15.4 | 131.5 | |
| **1f** | 6.45 | | 15.5 | 131.6 | |
| **1g** | 6.52 | | 15.3 | 131.7 | |
| **6a** | | 6.55 | 15.0 | | 134.9 |
| **6b** | | 6.53 | 14.8 | | 134.7 |
| **6c** | | 6.54 | 14.9 | | 134.6 |
| **6d** | | 6.53 | 14.9 | | 134.8 |
| **6e** | | 6.48 | 14.9 | | 134.1 |
| **6f** | | 6.51 | 14.9 | | 134.8 |
| **6g** | | 6.55 | 14.9 | | 134.4 |

*a*) Solvents: see Experimental.

## Experimental

All melting points were determined on a Yanagimoto hot-stage apparatus and are uncorrected. TLC was performed on Kieselgel 60 $F_{254}$ precoated glass plates (Merck). Low-pressure column chromatography was performed by using 230—400 mesh Silica gel 60 (Nakarai) and a Kiriyama ILC-135-10 low-pressure pump system with typical flow pressure of 3 kg/cm$^2$. Mass spectra (MS) were recorded on a Hitachi M-52 spectrometer, and high-resolution MS on a Hitachi M-80 spectrometer. Infrared (IR) spectra were taken with a JASCO IR-810 spectrophotometer. $^1$H-NMR spectra were recorded either on a JEOL JNM-FX-100 (100 MHz) or a JEOL JNM-GX-270 (270 MHz) spectrometer, and $^{13}$C-NMR spectra on the former spectrometer operating at 25.00 MHz, with tetramethylsilane as an internal standard. Chemical shifts are quoted in $\delta$ (ppm).

**Preparation of 2-Anilino-5-methyl-1,4-benzoquinones 9a—h and 2-Anilino-6-methyl-1,4-benzoquinones 10a—h** The method of Jacini[10a)] and Hanger *et al.*[10b)] was used with slight modifications. A mixture of **7** (1780 mg, 14.6 mmol) and water (220 ml) was heated on a water-bath to dissolve **7** as much as possible. After the mixture had cooled to room temperature, a solution of an aniline **8a**—**h** (7.3 mmol) either in a mixture of AcOH (0.5 ml) and water (5 ml) (in the case of **8a**, **8b**, and **8e**—**g**) or in AcOH (17 ml) (in the case of **8c**, **8d**, and **8h**) was added to the resulting suspension, and the whole mixture was stirred at room temperature for 5 h. The reaction mixture was extracted with chloroform, and the extract was washed with water and dried over magnesium sulfate. The solvent was evaporated off under reduced pressure and the resulting residue was chromatographed under low pressure with benzene as an eluent. The earlier fractions yielded the corresponding **9a**—**h**, which were recrystallized from methanol. Compounds **10a**—**h** were isolated from the later fractions with the same solvent and recrystallized from methanol.[13)]

2-Anilino-5-methyl-1,4-benzoquinone (**9a**): Yield 60%. Violet sticks, mp 155—157 °C (dec.) [lit.[8)] mp 150—151 °C (dec.)]. *Anal.* Calcd for $C_{13}H_{11}NO_2$: C, 73.22; H, 5.20; N, 6.57. Found: C, 73.02; H, 5.16; N, 6.54. MS *m/z*: 213 ($M^+$). $^1$H-NMR ($CDCl_3$) $\delta$: 7.50—7.02 (6H, m, Ar-H + NH), 6.56 (1H, q, $J$ = 1.7 Hz, H-6), 6.16 (1H, s, H-3), 2.10 (3H, d, $J$ = 1.7 Hz, 5-$CH_3$).

2-Anilino-6-methyl-1,4-benzoquinone (**10a**): Yield 31%. Brown needles, mp 154—155 °C [lit.[8)] mp 155—156 °C (dec.)]. *Anal.* Calcd for $C_{13}H_{11}NO_2$: C, 73.22; H, 5.20; N, 6.57. Found: C, 73.26; H, 5.10; N, 6.60. MS *m/z*: 213 ($M^+$). $^1$H-NMR ($CDCl_3$) $\delta$: 7.50—7.00 (6H, m, Ar-H + NH), 6.51 (1H, dq, $J$ = 2.4, 1.7 Hz, H-5), 6.11 (1H, d, $J$ = 2.4 Hz, H-3), 2.07 (3H, d, $J$ = 1.7 Hz, 6-$CH_3$).

2-(4-Methylanilino)-5-methyl-1,4-benzoquinone (**9b**): Yield 64%. Violet needles, mp 122—123 °C. *Anal.* Calcd for $C_{14}H_{13}NO_2$: C, 73.99; H, 5.77; N, 6.16. Found: C, 73.89; H, 5.74; N, 6.01. MS *m/z*: 227 ($M^+$). $^1$H-NMR ($CDCl_3$) $\delta$: 7.50—6.80 (5H, m, Ar-H + NH), 6.52 (1H, q, $J$ = 1.7 Hz, H-6), 6.07 (1H, s, H-3), 2.32 (3H, s, Ar-$CH_3$), 2.07 (3H, d, $J$ = 1.7 Hz, 5-$CH_3$).

2-(4-Methylanilino)-6-methyl-1,4-benzoquinone (**10b**): Yield 30%. Reddish violet needles, mp 127—128 °C. *Anal.* Calcd for $C_{14}H_{13}NO_2$: C, 73.99; H, 5.77; N, 6.16. Found: C, 73.89; H, 5.74; N, 6.01. MS *m/z*: 227 ($M^+$). $^1$H-NMR ($CDCl_3$) $\delta$: 7.28—6.98 (5H, m, Ar-H+NH), 6.49 (1H, sextet, $J$=2.4, 1.7 Hz, H-5), 6.04 (1H, d, $J$=2.4 Hz, H-3), 2.33 (3H, s, Ar-$CH_3$), 2.07 (3H, d, $J$=1.7 Hz, 6-$CH_3$).

2-(4-Chloroanilino)-5-methyl-1,4-benzoquinone (**9c**): Yield 61%. Brown prisms, mp 157—158 °C. *Anal.* Calcd for $C_{13}H_{10}ClNO_2$: C, 63.04; H, 4.07; N, 5.66. Found: C, 63.06; H, 3.91; N, 5.52. MS *m/z*: 249 ($M^+$ +2), 247 ($M^+$). $^1$H-NMR ($CDCl_3$) $\delta$: 7.42—7.05 (5H, m, Ar-H+NH), 6.56 (1H, q, $J$=1.7 Hz, H-6), 6.09 (1H, s, H-3), 2.09 (3H, d, $J$=1.7 Hz, 5-$CH_3$).

2-(4-Chloroanilino)-6-methyl-1,4-benzoquinone (**10c**): Yield 27%. Violet needles, mp 168—170 °C. *Anal.* Calcd for $C_{13}H_{10}ClNO_2$: C, 63.04; H, 4.07; N, 5.66. Found: C, 62.95; H, 3.86; N, 5.60. MS *m/z*: 249 ($M^+$+2), 247 ($M^+$). $^1$H-NMR ($CDCl_3$) $\delta$: 7.42—7.00 (5H, m, Ar-H+NH), 6.51 (1H, dq, $J$=2.4, 1.7 Hz, H-5), 6.05 (1H, d, $J$=2.4 Hz, H-3), 2.07 (3H, d, $J$=1.7 Hz, 6-$CH_3$).

2-(4-Fluoroanilino)-5-methyl-1,4-benzoquinone (**9d**): Yield 57%. Violet needles, mp 176—178 °C. *Anal.* Calcd for $C_{13}H_{10}FNO_2$: C, 67.53; H, 4.36; N, 6.06. Found: C, 67.51; H, 4.35; N, 5.97. MS *m/z*: 231 ($M^+$). $^1$H-NMR ($CDCl_3$) $\delta$: 7.22—6.96 (5H, m, Ar-H+NH), 6.55 (1H, q, $J$=1.7 Hz, H-6), 6.00 (1H, s, H-3), 2.09 (3H, d, $J$=1.7 Hz, 5-$CH_3$).

2-(4-Fluoroanilino)-6-methyl-1,4-benzoquinone (**10d**): Yield 29%. Violet prisms, mp 141—143 °C. *Anal.* Calcd for $C_{13}H_{10}FNO_2$: C, 67.53; H, 4.36; N, 6.06. Found: C, 67.57; H, 4.38; N, 6.07. MS *m/z*: 231 ($M^+$). $^1$H-NMR ($CDCl_3$) $\delta$: 7.30—6.90 (5H, m, Ar-H+NH), 6.51 (1H, sextet, $J$=2.4, 1.7 Hz, H-5), 5.95 (1H, d, $J$=2.4 Hz, H-3), 2.09 (3H, d, $J$=1.7 Hz, 6-$CH_3$).

2-(4-Methoxyanilino)-5-methyl-1,4-benzoquinone (**9e**): Yield 64%. Violet needles, mp 137—138 °C. *Anal.* Calcd for $C_{14}H_{13}NO_3$: C, 69.12; H, 5.39; N, 5.76. Found: C, 69.30; H, 5.34; N, 5.51. MS *m/z*: 243 ($M^+$). $^1$H-NMR ($CDCl_3$) $\delta$: 7.22—6.78 (5H, m, Ar-H+NH), 6.52 (1H, q, $J$=1.7 Hz, H-6), 5.96 (1H, s, H-3), 3.80 (3H, s, $OCH_3$), 2.09 (3H, d, $J$=1.7 Hz, 5-$CH_3$).

2-(4-Methoxyanilino)-6-methyl-1,4-benzoquinone (**10e**): Yield 32%. Violet needles, mp 141—143 °C. *Anal.* Calcd for $C_{14}H_{13}NO_3$: C, 69.12; H, 5.39; N, 5.76. Found: C, 69.05; H, 5.36; N, 5.82. MS *m/z*: 243 ($M^+$). $^1$H-NMR ($CDCl_3$) $\delta$: 7.22—6.78 (5H, m, Ar-H+NH), 6.48 (1H, sextet, $J$=2.4, 1.7 Hz, H-5), 5.91 (1H, d, $J$=2.4 Hz, H-3), 3.80 (3H, s, $OCH_3$), 2.06 (3H, d, $J$=1.7 Hz, 6-$CH_3$).

2-(3-Methoxyanilino)-5-methyl-1,4-benzoquinone (**9f**): Yield 50%. Reddish violet needles, mp 110—112 °C. *Anal.* Calcd for $C_{14}H_{13}NO_3$: C, 69.12; H, 5.39; N, 5.76. Found: C, 69.00; H, 5.32; N, 5.85. MS *m/z*: 243 ($M^+$). $^1$H-NMR ($CDCl_3$) $\delta$: 7.38—6.60 (5H, m, Ar-H+NH), 6.55 (1H, q, $J$=1.7 Hz, H-6), 6.19 (1H, s, H-3), 3.80 (3H, s, $OCH_3$), 2.09 (3H, d, $J$=1.7 Hz, 5-$CH_3$).

2-(3-Methoxyanilino)-6-methyl-1,4-benzoquinone (**10f**): Yield 26%. Violet needles, mp 96—98 °C. *Anal.* Calcd for $C_{14}H_{13}NO_3$: C, 69.12; H, 5.39; N, 5.76. Found: C, 69.21; H, 5.36; N, 5.75. MS *m/z*: 243 ($M^+$). $^1$H-NMR ($CDCl_3$) $\delta$: 7.38—6.60 (5H, m, Ar-H+NH), 6.50 (1H, dq, $J$=2.4, 1.7 Hz, H-5), 6.14 (1H, d, $J$=2.4 Hz, H-3), 3.80 (3H, s, $OCH_3$), 2.07 (3H, d, $J$=1.7 Hz, 6-$CH_3$).

2-(2-Methoxyanilino)-5-methyl-1,4-benzoquinone (**9g**): Yield 60%. Brown needles, mp 119—121 °C (lit.[10a] mp 138°C). *Anal.* Calcd for $C_{14}H_{13}NO_3$: C, 69.12; H, 5.39; N, 5.76. Found: C, 68.82; H, 5.32; N, 5.71. MS *m/z*: 243 ($M^+$). $^1$H-NMR ($CDCl_3$) $\delta$: 7.68 (1H, br s, NH), 7.36—6.84 (4H, m, Ar-H), 6.54 (1H, q, $J$=1.7 Hz, H-6), 6.21 (1H, s, H-3), 3.87 (3H, s, $OCH_3$), 2.09 (3H, d, $J$=1.7 Hz, 5-$CH_3$).

2-(2-Methoxyanilino)-6-methyl-1,4-benzoquinone (**10g**): Yield 31%. Violet sticks, mp 171—172 °C. *Anal.* Calcd for $C_{14}H_{13}NO_3$: C, 69.12; H, 5.39; N, 5.76. Found: C, 69.04; H, 5.31; N, 5.75. MS *m/z*: 243 ($M^+$). $^1$H-NMR ($CDCl_3$) $\delta$: 7.68 (1H, br s, NH), 7.34—6.83 (4H, m, Ar-H), 6.49 (1H, dq, $J$=2.4, 1.7 Hz, H-5), 6.16 (1H, d, $J$=2.4 Hz, H-3), 3.87 (3H, s, $OCH_3$), 2.07 (3H, d, $J$=1.7 Hz, 6-$CH_3$).

2-(4-Hydroxyanilino)-5-methyl-1,4-benzoquinone (**9h**): Yield 45%. Violet sticks, mp 146—148 °C. *Anal.* Calcd for $C_{13}H_{11}NO_3$: C, 68.11; H, 4.84; N, 6.11. Found: C, 68.19; H, 4.76; N, 6.03. MS *m/z*: 229 ($M^+$). $^1$H-NMR (acetone-$d_6$) $\delta$: 8.50 (1H, br s, OH or NH), 7.87 (1H, br s, NH or OH), 7.28—6.82 (4H, m, Ar-H), 6.57 (1H, q, $J$=1.7 Hz, H-6), 5.78 (1H, s, H-3), 2.01 (3H, d, $J$=1.7 Hz, 5-$CH_3$).

2-(4-Hydroxyanilino)-6-methyl-1,4-benzoquinone (**10h**): Yield 19%. Violet prisms, mp 210—212°C. *Anal.* Calcd for $C_{13}H_{11}NO_3$: C, 68.11; H, 4.84; N, 6.11. Found: C, 67.86; H, 4.79; N, 5.98. MS *m/z*: 229 ($M^+$). $^1$H-NMR (DMSO-$d_6$) $\delta$: 9.46 (1H, br s, OH or NH), 8.70 (1H, br s, NH or OH), 7.22—6.60 (4H, m, Ar-H), 6.49 (1H, br s, H-5), 5.57 (1H, d, $J$=2.4 Hz, H-3), 1.96 (3H, d, $J$=1.7 Hz, 6-$CH_3$).

**Exclusive Preparation of 9a** Method A: A mixture of 2-bromo-6-methyl-1,4-benzoquinone (**16**)[17] (800 mg, 4.0 mmol) and water (110 ml) was heated on a water-bath to dissolve **16** as much as possible. After the mixture had cooled to room temperature, a solution of **8a** (190 mg, 2.0 mmol) in a mixture of AcOH (0.5 ml) and water (5 ml) was added to the resulting suspension, and the whole mixture was stirred at room temperature for 16 h, then extracted with chloroform. The extract was washed with water and dried over magnesium sulfate. The solvent was evaporated off under reduced pressure and the resulting residue was chromatographed under low pressure. Elution with benzene followed by recrystallization from methanol gave 2-anilino-3-bromo-5-methyl-1,4-benzoquinone (**17**) (540 mg, 90%) as dark red flakes, mp 121—123 °C (dec.). *Anal.* Calcd for $C_{13}H_{10}BrNO_2 \cdot 1/10\ H_2O$: C, 53.12; H, 3.49; N, 4.77. Found: C, 52.89; H, 3.26; N, 4.47. MS *m/z*: 293 ($M^+$ +2), 291 ($M^+$). $^1$H-NMR ($CDCl_3$) $\delta$: 7.42—6.99 (6H, m, Ar-H+NH), 6.58 (1H, q, $J$=1.5 Hz, H-6), 2.15 (3H, d, $J$=1.5 Hz, $CH_3$).

A mixture of **17** (150 mg, 0.51 mmol) and methanol (30 ml) was hydrogenated catalytically in the presence of 10% palladium on charcoal (15 mg) at room temperature and 4 kg/cm$^2$ pressure for 1h. The catalyst was filtered off and washed with a small amount of methanol. Powdered sodium hydrogencarbonate (80 mg) was added to the combined filtrate and washings, and the mixture was stirred at room temperature in a vessel open to the air for 2 h. The reaction mixture was diluted with water and extracted with chloroform. The extract was washed with water and dried over magnesium sulfate, and the solvent was evaporated off under reduced pressure. The resulting residue was purified by column chromatography under low pressure with benzene followed by recrystallization from methanol to give **9a** (70 mg, 64%).

Method B: A solution of butyllithium in hexane (4 mmol) was added dropwise to a stirred solution of **8a** (370 mg, 4 mmol) in anhydrous tetrahydrofuran (10 ml) at −78 °C under a nitrogen atmosphere. The mixture was stirred at the same temperature for 1 h and at room temperature for 1 h, then 4,4-dimethoxy-2-methylcyclohexa-2,5-dienone (**18**)[18] (500 mg, 4 mmol) was added to the mixture at −78 °C. The mixture

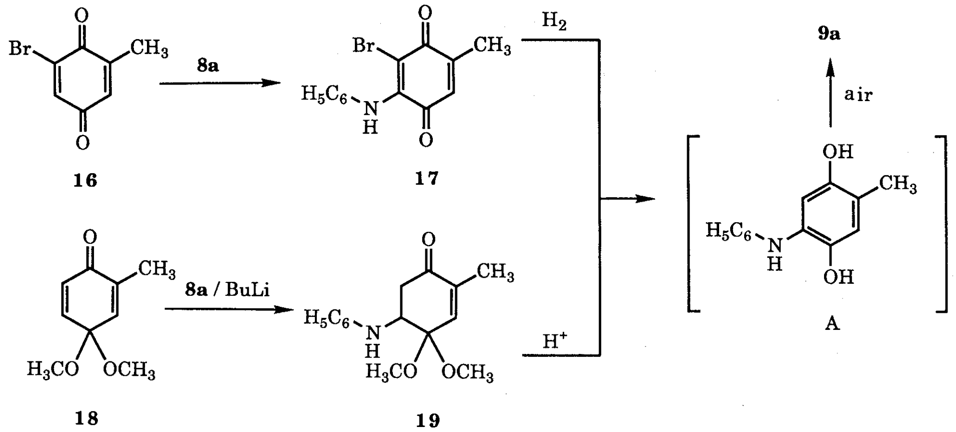


Chart 3

was stirred at the same temperature for 1 h, then at room temperature for 1 h. The reaction mixture was poured into water and extracted with dichloromethane. The extract was washed with water and dried over magnesium sulfate. Evaporation of the solvent gave the crude 5-anilino-4,4-dimethoxy-2-methylcyclohex-2-enone (**19**), which was purified by column chromatography with benzene followed by recrystallization from hexane to give pale yellow prisms (320 mg, 37%), mp 96—98 °C. *Anal.* Calcd for $C_{15}H_{19}NO_3$: C, 68.94; H, 7.33; N, 5.36. Found: C, 68.87; H, 7.36; N, 5.32. MS *m*/*z*: 261 ($M^+$). $^1$H-NMR ($CDCl_3$) $\delta$: 7.24—7.07 (2H, m, Ar-H), 6.77—6.50 (4H, m, Ar-H + H-3),[19] 4.04 (2H, br, NH + H-5),[20] 3.32 and 3.21 (each 3H, each s, $OCH_3 \times 2$), 2.84 (2H, br d, $J$ = 3.9 Hz, changed to sharp d on addition of $D_2O$, 6-$CH_2$), 1.86 (3H, d, $J$ = 1.5 Hz, $CH_3$).

A mixture of **19** (100 mg, 0.38 mmol), methanol (5 ml), water (5 ml), and AcOH (0.5 ml) was refluxed for 4 h, and then stirred at room temperature in a vessel open to the air for 27 h. The mixture was extracted with chloroform. The extract was washed with water and dried over magnesium sulfate. The solvent was evaporated off under reduced pressure and the resulting residue was purified by column chromatography under low pressure with benzene followed by recrystallization from methanol to give **9a** (70 mg, 82%).

In this procedure, the low isolation yield of **19** was ascribable to its instability toward chromatographic purification on silica gel. When the crude **19** was subjected to hydrolysis and subsequent aerial oxidation without purification, **9a** was obtained in 80% overall yield from **18**.

**3-Methylcarbazole-1,4-quinones 1a—g** A mixture of **9a—g** (0.5 mmol) and Pd(OAc)$_2$ (110 mg, 0.5 mmol) in AcOH (10 ml) was refluxed for 50 min under an argon atmosphere. The insoluble matter was filtered off and washed with acetone. The combined filtrate and washings were evaporated to dryness under reduced pressure, and the residue was chromatographed under low pressure with hexane–ethyl acetate (4 : 1, v/v) and recrystallized from acetone to give the corresponding **1a—g**. Compound **1a** was found to be identical (IR, $^1$H- and $^{13}$C-NMR, MS, and co-TLC) with natural murrayaquinone-A.[1a,b]

3-Methylcarbazole-1,4-quinone (murrayaquinone-A) (**1a**): Yield 64%. Red needles, mp 237—239 °C (dec.) [lit.[1a,b] mp 246—247 °C; lit.[3a,b] mp 240—241 °C; lit[3c] mp 241 °C (dec.)]. *Anal.* Calcd for $C_{13}H_9NO_2$: C, 73.92; H, 4.30; N, 6.63. Found: C, 73.95; H, 4.08; N, 6.32. IR $\nu_{\max}^{\mathrm{KBr}}$ cm$^{-1}$: 3220, 1665, 1640, 1605. MS *m*/*z*: 211 ($M^+$), 183, 168, 155, 154, 143, 115. $^1$H-NMR ($CDCl_3$) $\delta$: 9.02 (1H, br s, NH), 8.22 (1H, dt, $J$ = 5.0, 1.0 Hz, H-5), 7.60—7.30 (3H, m, H-6, -7, and -8), 6.50 (1H, q, $J$ = 1.5 Hz, H-2), 2.18 (3H, d, $J$ = 1.5 Hz, 3-$CH_3$). $^{13}$C-NMR ($CDCl_3$ + DMSO-$d_6$) $\delta$: 183.1 (s), 180.0 (s), 148.0 (s), 137.5 (s), 135.8 (s), 131.5 (d, C-2), 126.1 (d), 123.6 (s), 123.6 (d), 121.7 (d), 115.7 (s), 113.7 (d), 15.7 (q, 3-$CH_3$).

3,6-Dimethylcarbazole-1,4-quinone (**1b**): Yield 79%. Red needles, mp 228—230 °C (dec.). *Anal.* Calcd for $C_{14}H_{11}NO_2$: C, 74.65; H, 4.92; N, 6.22. Found: C, 74.47; H, 4.78; N, 5.88. MS *m*/*z*: 225 ($M^+$). $^1$H-NMR (DMSO-$d_6$) $\delta$: 12.67 (1H, br s, NH), 7.83 (1H, dd, $J$ = 1.5, 0.5 Hz, H-5), 7.43 (1H, d, $J$ = 8.5 Hz, H-8), 7.19 (1H, dd, $J$ = 8.5, 1.5 Hz, H-7), 6.58 (1H, q, $J$ = 1.7 Hz, H-2), 2.42 (3H, s, 6-$CH_3$), 2.06 (3H, d, $J$ = 1.7 Hz, 3-$CH_3$). $^{13}$C-NMR (DMSO-$d_6$) $\delta$: 182.8 (s), 179.8 (s), 147.8 (s), 135.8 (s), 133.0 (s), 131.5 (d, C-2), 127.9 (d), 123.9 (s), 120.9 (d), 114.9 (s), 113.4 (d), 21.2 (q), 15.5 (q, 3-$CH_3$).

6-Chloro-3-methylcarbazole-1,4-quinone (**1c**): Yield 46%. Orange needles, mp 253—254 °C (dec.). *Anal.* Calcd for $C_{13}H_8ClNO_2$: C, 63.56; H, 3.28; N, 5.70. Found: C, 63.55; H, 3.09; N, 5.60. MS *m*/*z*: 247 ($M^+$ + 2), 245 ($M^+$). $^1$N-NMR (DMSO-$d_6$) $\delta$: 12.96 (1H, br s, NH), 7.97 (1H, dd, $J$ = 2.0, 0.7 Hz, H-5), 7.56 (1H, dd, $J$ = 8.8, 0.7 Hz, H-8), 7.38 (1H, dd, $J$ = 8.8, 2.0 Hz, H-7), 6.63 (1H, q, $J$ = 1.7 Hz, H-2), 2.07 (3H, d, $J$ = 1.7 Hz, 3-$CH_3$). $^{13}$C-NMR (DMSO-$d_6$) $\delta$: 182.2 (s), 179.5 (s), 147.7 (s), 136.5 (s), 135.7 (s), 131.5 (d, C-2), 128.2 (s), 126.1 (d), 124.1 (s), 120.3 (d), 115.3 (d), 114.5 (s), 15.4 (q, 3-$CH_3$).

6-Fluoro-3-methylcarbazole-1,4-quinone (**1d**): Yield 83%. Orange needles, mp 235—236 °C (dec.). *Anal.* Calcd for $C_{13}H_8FNO_2$: C, 68.12; H, 3.52; N, 6.11. Found: C, 67.91; H, 3.31; N, 5.97 . MS *m*/*z*: 229 ($M^+$). $^1$H-NMR (DMSO-$d_6$) $\delta$: 12.94 (1H, br s, NH), 7.67 (1H, ddd, $J$ = 9.3, 2.5, 0.5 Hz, H-5), 7.55 (1H, ddd, $J$ = 9.3, 4.6, 0.5 Hz, H-8), 7.24 (1H, td, $J$ = 9.3, 2.5 Hz, H-7), 6.63 (1H, q, $J$ = 1.7 Hz, H-2), 2.07 (3H, d, $J$ = 1.7 Hz, 3-$CH_3$). $^{13}$C-NMR (DMSO-$d_6$) $\delta$: 182.4 (s), 179.5 (s), 164.1 and 154.6 (each s, fluorine-coupled carbon), 147.9 (s), 137.0 (s), 134.0 (s), 131.6 (d, C-2), 124.0 and 123.6 (each s, fluorine-coupled carbon), 115.5 and 115.2 (each d, fluorine-coupled carbon), 115.4 (s), 115.4 and 114.4 (each d, fluorine-coupled carbon), 106.3 and 105.3 (each d, fluorine-coupled carbon), 15.4 (q, 3-$CH_3$).

6-Methoxy-3-methylcarbazole-1,4-quinone (**1e**): Yield 52%. Red needles, mp 249—250 °C (dec.). *Anal.* Calcd for $C_{14}H_{11}NO_3$: C, 69.70; H, 4.59; N, 5.80. Found: C, 69.78; H, 4.43; N, 5.49. MS *m*/*z*: 241 ($M^+$). $^1$H-NMR (DMSO-$d_6$) $\delta$: 12.70 (1H, br s, NH), 7.44 (1H, d, $J$ = 2.5 Hz, H-5), 7.42 (1H, d, $J$ = 9.0 Hz, H-8), 7.00 (1H, dd, $J$ = 9.0, 2.5 Hz, H-7), 6.58 (1H, q, $J$ = 1.7 Hz, H-2), 3.81 (3H, s, 6-$OCH_3$), 2.06 (3H, d, $J$ = 1.7 Hz, 3-$CH_3$). $^{13}$C-NMR (DMSO-$d_6$) $\delta$: 183.1 (s), 179.3 (s), 158.7 (s), 147.0 (s), 138.8 (s), 134.8 (s), 131.5 (d, C-2), 122.3 (d), 117.7 (s), 115.8 (s), 114.9 (d), 95.0 (d), 55.2 (q), 15.4 (q, 3-$CH_3$).

7-Methoxy-3-methylcarbazole-1,4-quinone (**1f**): Yield 65%. Brown needles, mp 236—238 °C (dec.) [lit.[3a,b] mp 240 °C (dec.)]. *Anal.* Calcd for $C_{14}H_{11}NO_3 \cdot 1/10\ H_2O$: C, 69.18; H, 4.64; N, 5.76. Found: C, 69.13; H, 4.41; N, 5.79. High-resolution MS *m*/*z*: Calcd for $C_{14}H_{11}NO_3$: 241.0737. Found: 241.0730. $^1$H-NMR ($CDCl_3$) $\delta$: 8.90 (1H, br s, NH), 8.07 (1H, d, $J$ = 9.0 Hz, H-5), 6.98 (1H, dd, $J$ = 9.0, 2.2 Hz, H-6), 6.84 (1H, d, $J$ = 2.2 Hz, H-8), 6.45 (1H, q, $J$ = 1.7 Hz, H-2), 3.87 (3H, s, 7-$OCH_3$), 2.15 (3H, d, $J$ = 1.7 Hz, 3-$CH_3$). $^{13}$C-NMR (DMSO-$d_6$) $\delta$: 182.8 (s), 179.6 (s), 156.8 (s), 147.8 (s), 135.7 (s), 132.6 (s), 131.6 (d, C-2), 124.5 (s), 117.4 (d), 115.1 (s), 114.8 (d), 101.6 (d), 55.3 (q), 15.5 (q, 3-$CH_3$).

8-Methoxy-3-methylcarbazole-1,4-quinone (**1g**): Yield 55%. Dark red prisms, mp 220—221 °C (dec.). *Anal.* Calcd for $C_{14}H_{11}NO_3$: C, 69.70; H, 4.59; N, 5.80. Found: C, 69.49; H, 4.39; N, 5.84. MS *m*/*z*: 241 ($M^+$). $^1$H-NMR (DMSO-$d_6$) $\delta$: 12.97 (1H, br s, NH), 7.56 (1H, dd, $J$ = 8.1, 0.7 Hz, H-5), 7.18 (1H, t, $J$ = 8.1 Hz, H-6), 6.86 (1H, dd, $J$ = 8.1, 0.7 Hz, H-7), 6.52 (1H, q, $J$ = 1.5 Hz, H-2), 3.92 (3H, s, 8-$OCH_3$), 2.03 (3H, d, $J$ = 1.5 Hz, 3-$CH_3$). $^{13}$C-NMR (DMSO-$d_6$) $\delta$: 183.0 (s), 179.5 (s), 147.4 (s), 135.6 (s), 131.7 (d, C-2), 128.2 (s), 125.0 (s), 124.7 (d), 115.8 (s), 113.5 (d), 106.0 (d), 55.5 (q), 15.3 (q, 3-$CH_3$).

**7-Acetamido-(12) and 5-Acetamido-2,2-dimethyl-2*H*-chromene (13)** Potassium carbonate (600 mg, 4.4 mmol), potassium iodide (150 mg, 0.9 mmol), and water (2 drops) were added successively to a solution of **11** (1000 mg, 6.6 mmol) in acetone (15 ml), followed by addition of 3-chloro-3-methyl-1-butyne[11] (740 mg, 7.2 mmol). The mixture was refluxed with stirring for 2 d under a nitrogen atmosphere. More 3-chloro-3-methyl-1-butyne (740 mg, 7.2 mmol) in acetone (1 ml) was introduced and the refluxing was continued for a further 2d. Insoluble matter was filtered off and washed with acetone. The combined filtrate and washings were evaporated to dryness under reduced pressure. The residue was taken up in ether, washed successively with 3% aqueous sodium hydroxide and water, then dried over anhydrous potassium carbonate. Evaporation of the solvent gave the crude 1,1-dimethylpropargyl ether of **11** (870 mg) as an oil. The propargyl ether was dissolved in *N*,*N*-diethylaniline[21] (5 ml) and the mixture was refluxed for 2 h. After addition of ether, the mixture was washed successively with cold dilute hydrochloric acid and water, and dried over anhydrous potassium carbonate. The solvent was evaporated off and the resulting residue was chromatographed under low pressure with hexane–ethyl acetate (2 : 1, v/v) as an eluent. The earlier fractions yielded **12** (150 mg, 10%) as a viscous oil (lit.[22] mp 80—81 °C). High-resolution MS *m*/*z*: Calcd for $C_{13}H_{15}NO_2$: 217.1102. Found: 217.1120. $^1$H-NMR ($CDCl_3$) $\delta$: 7.98 (1H, br s, NH), 7.00 (1H, d, $J$ = 1.5 Hz, H-8), 6.88 (1H, dd, $J$ = 8.0, 1.5 Hz, H-6), 6.82 (1H, d, $J$ = 8.0 Hz, H-5), 6.23 (1H, d, $J$ = 10.0 Hz, H-4), 5.48 (1H, d, $J$ = 10.0 Hz, H-3), 2.09 (3H, s, $COCH_3$), 1.37 (6H, s, $CH_3 \times 2$).

Compound **13** was isolated from the later fractions with the same solvent and recrystallized from benzene–hexane to give colorless flakes (120 mg, 8%), mp 138—140 °C. *Anal.* Calcd for $C_{13}H_{15}NO_2 \cdot 1/10H_2O$: C, 71.27; H, 6.99; N, 6.39. Found: C, 71.40; H, 7.04; N, 6.45. High-resolution MS *m*/*z*: Calcd for $C_{13}H_{15}NO_2$: 217.1102. Found: 217.1110. $^1$H-NMR (270 MHz, $CDCl_3$) $\delta$: 7.14 (1H, d, $J$ = 8.0 Hz, H-6), 7.08 (1H, br s, NH), 7.09 (1H, t, $J$ = 8.0 Hz, H-7), 6.67 (1H, d, $J$ = 8.0 Hz, H-8), 6.35 (1H, d, $J$ = 9.7 Hz, H-4), 5.68 (1H, d, $J$ = 9.7 Hz, H-3), 2.18 (3H, s, $COCH_3$), 1.43 (6H, s, $CH_3 \times 2$).

**6-Acetamido-2,2-dimethyl-2*H*-chromene (15)** Procedures similar to those mentioned above for **12** and **13** starting from **14** (1000 mg, 6.6 mmol), followed by recrystallization from benzene–hexane, gave **15** (420 mg, 29%) as colorless flakes, mp 117—119 °C (lit.[14] mp 126—126.8 °C). *Anal.* Calcd for $C_{13}H_{15}NO_2$: C, 71.86; H, 6.96; N, 6.45. Found: C, 71.82; H, 6.91; N, 6.39. MS *m*/*z*: 217 ($M^+$). $^1$H-NMR ($CDCl_3$) $\delta$: 7.61 (1H, br s, NH), 7.22 (1H, d, $J$ = 2.4 Hz, H-5), 7.03 (1H, dd, $J$ = 8.5, 2.4 Hz, H-7), 6.67 (1H, d, $J$ = 8.5 Hz, H-8), 6.23 (1H, d, $J$ = 9.8 Hz, H-4), 5.59 (1H, d, $J$ = 9.8 Hz, H-3), 2.10 (3H, s, $COCH_3$), 1.39 (6H, s, $CH_3 \times 2$).

**7-Amino- (8i), 5-Amino- (8j), and 6-Amino-2,2-dimethyl-2*H*-chromene (8k)** A mixture of an acetamidochromene **12**, **13**, or **15** (110 mg, 0.5 mmol), 6 N hydrochloric acid (5 ml), and ethanol (5 ml) was refluxed for 2 h. After evaporation of the solvent, water was added to the residue, and the mixture was washed with ether. The aqueous solution was basified with an aqueous ammonia solution and extracted with chloroform. The extract was dried over anhydrous potassium carbonate. In the case of the hydrolysis of **12**, evaporation of the extract under reduced pressure gave a viscous oil, which was subjected to silica gel column chromatography with benzene as an eluent to give **8i** (49%) as colorless crystals, mp 35—36 °C. High-resolution MS *m/z*: Calcd for $C_{11}H_{13}NO$: 175.0997. Found: 175.1008. $^1$H-NMR ($CDCl_3$) $\delta$: 6.74 (1H, d, $J$=8.0 Hz, H-5), 6.22 (1H, d, $J$=10.0 Hz, H-4), 6.14 (1H, dd, $J$=8.0, 1.5 Hz, H-6), 6.10 (1H, d, $J$=1.5 Hz, H-8), 5.38 (1H, d, $J$=10.0 Hz, H-3), 3.42 (2H, br s, $NH_2$), 1.38 (6H, s, $CH_3 \times 2$).

In the case of the hydrolysis of **13** or **15**, evaporation of the extract under reduced pressure gave **8j** or **8k** as a viscous oil, which was used in the subsequent step without further purification.

**8j**: Yield 99%. High-resolution MS *m/z*: Calcd for $C_{11}H_{13}NO$: 175.0997. Found: 175.1008. $^1$H-NMR ($CDCl_3$) $\delta$: 6.88 (1H, t, $J$=8.0 Hz, H-7), 6.33 (1H, d, $J$=10.0 Hz, H-4), 6.24 (1H, dt, $J$=8.0, 1.5 Hz, H-8), 6.20 (1H, dd, $J$=8.0, 1.5 Hz, H-6), 5.56 (1H, d, $J$=10.0 Hz, H-3), 3.60 (2H, br s, $NH_2$), 1.38 (6H, s, $CH_3 \times 2$).

**8k**[23]: Yield 97%. High-resolution MS *m/z*: Calcd for $C_{11}H_{13}NO$: 175.0997. Found: 175.0997. $^1$H-NMR ($CDCl_3$) $\delta$: 6.61 (1H, d, $J$=8.3 Hz, H-8), 6.44 (1H, dd, $J$=8.3, 2.7 Hz, H-7), 6.35 (1H, d, $J$=2.7 Hz, H-5), 6.21 (1H, d, $J$=9.8 Hz, H-4), 5.59 (1H, d, $J$=9.8 Hz, H-3), 3.10 (2H, br s, $NH_2$), 1.38 (6H, s, $CH_3 \times 2$).

**Condensation of the 7-Amino-, 5-Amino-, and 6-Aminochromenes 8i, 8j, and 8k with Methyl-1,4-benzoquinone (7)** A mixture of **7** (250 mg, 2 mmol) and water (50 ml) was heated on a water-bath to dissolve **7** as much as possible. After the mixture had cooled to room temperature, a mixture of an aminochromene **8i**, **8j**, or **8k** (180 mg, 1 mmol), AcOH (2 ml), and water (2 ml) was added to the resulting suspension, and the whole mixture was stirred at room temperature for 5 h, then extracted with ethyl acetate. The same work-up as described for the preparation of **9a**—**h** and **10a**—**h** gave the corresponding 2-chromenylamino-5-methylbenzoquinones **9i**, **9j**, and **9k** together with the 6-methyl isomers **10i**, **10j**, and **10k**.

2-(2,2-Dimethyl-2*H*-chromen-7-ylamino)-5-methyl-1,4-benzoquinone (**9i**): Yield 14%. Violet prisms from methanol, mp 134—135 °C. *Anal.* Calcd for $C_{18}H_{17}NO_3$: C, 73.20; H, 5.80; N, 4.74. Found: C, 73.31; H, 5.80; N, 4.31. MS *m/z*: 295 ($M^+$). $^1$H-NMR ($CDCl_3$) $\delta$: 7.22 (1H, br s, NH), 6.89 (1H, d, $J$=8.5 Hz, H-5′), 6.66 (1H, d, $J$=2.2 Hz, H-8′), 6.64 (1H, dd, $J$=8.5, 2.2 Hz, H-6′), 6.54 (1H, q, $J$=1.5 Hz, H-6), 6.27 (1H, d, $J$=9.8 Hz, H-4′), 6.24 (1H, s, H-3), 5.57 (1H, d, $J$=9.8 Hz, H-3′), 2.10 (3H, d, $J$=1.5 Hz, 5-$CH_3$), 1.43 (6H, s, 2′-$CH_3 \times 2$).

2-(2,2-Dimethyl-2*H*-chromen-7-ylamino)-6-methyl-1,4-benzoquinone (**10i**): Yield 12%. Violet prisms from hexane, mp 110—111 °C. *Anal.* Calcd for $C_{18}H_{17}NO_3$: C, 73.20; H, 5.80; N, 4.74. Found: C, 72.87; H, 5.76; N, 4.62. MS *m/z*: 295 ($M^+$). $^1$H-NMR ($CDCl_3$) $\delta$: 7.24 (1H, br s, NH), 6.95 (1H, d, $J$=8.5 Hz, H-5′), 6.64 (1H, d, $J$=2.2 Hz, H-8′), 6.63 (1H, dd, $J$=8.5, 2.2 Hz, H-6′), 6.50 (1H, sextet, $J$=2.5, 1.5 Hz, H-5), 6.28 (1H, d, $J$=9.8 Hz, H-4′), 6.18 (1H, d, $J$=2.5 Hz, H-3), 5.58 (1H, d, $J$=9.8 Hz, H-3′), 2.08 (3H, d, $J$=1.5 Hz, 6-$CH_3$), 1.42 (6H, s, 2′-$CH_3 \times 2$).

2-(2,2-Dimethyl-2*H*-chromen-5-ylamino)-5-methyl-1,4-benzoquinone (**9j**): Yield 18%. Reddish violet prisms from hexane, mp 114—116 °C. *Anal.* Calcd for $C_{18}H_{17}NO_3$: C, 73.20; H, 5.80; N, 4.74. Found: C, 73.22; H, 5.86; N, 4.36. MS *m/z*: 295 ($M^+$). $^1$H-NMR ($CDCl_3$) $\delta$: 7.11 (1H, t, $J$=8.0 Hz, H-7′), 7.00 (1H, br s, NH), 6.74 and 6.70 (each 1H, each br d, $J$=8.0 Hz, H-6′ and -8′), 6.55 (1H, q, $J$=1.5 Hz, H-6), 6.30 (1H, d, $J$=10.0 Hz, H-4′), 5.72 (1H, s, H-3), 5.67 (1H, d, $J$=10.0 Hz, H-3′), 2.08 (3H, d, $J$=1.5 Hz, 5-$CH_3$), 1.42 (6H, s, 2′-$CH_3 \times 2$).

2-(2,2-Dimethyl-2*H*-chromen-5-ylamino)-6-methyl-1,4-benzoquinone (**10j**): Yield 11%. Reddish violet prisms from methanol, mp 198—200 °C. *Anal.* Calcd for $C_{18}H_{17}NO_3$: C, 73.20; H, 5.80; N, 4.74. Found: C, 73.09; H, 5.72; N, 4.48. MS *m/z*: 295 ($M^+$). $^1$H-NMR ($CDCl_3$) $\delta$: 7.11 (1H, t, $J$=7.8 Hz, H-7′), 7.00 (1H, br s, NH), 6.72 and 6.70 (each 1H, each br d, $J$=7.8 Hz, H-6′ and -8′), 6.48 (1H, sextet, $J$=2.5, 1.5 Hz, H-5), 6.30 (1H, d, $J$=10.0 Hz, H-4′), 5.68 (1H, d, $J$=2.5 Hz, H-3), 5.67 (1H, d, $J$=10.0 Hz, H-3′), 2.08 (3H, d, $J$=1.5 Hz, 6-$CH_3$), 1.43 (6H, s, 2′-$CH_3 \times 2$).

2-(2,2-Dimethyl-2*H*-chromen-6-ylamino)-5-methyl-1,4-benzoquinone (**9k**): Yield 53%. Violet prisms from methanol, mp 148—150 °C. *Anal.* Calcd for $C_{18}H_{17}NO_3$: C, 73.20; H, 5.80; N, 4.74. Found: C, 73.50; H, 5.77; N, 4.69. MS *m/z*: 295 ($M^+$). $^1$H-NMR ($CDCl_3$) $\delta$: 7.08 (1H, br s, NH), 6.92 (1H, dd, $J$=8.3, 2.7 Hz, H-7′), 6.82 (1H, d, $J$=2.7 Hz, H-5′), 6.75 (1H, d, $J$=8.3 Hz, H-8′), 6.52 (1H, q, $J$=1.7 Hz, H-6), 6.26 (1H, d, $J$=9.8 Hz, H-4′), 5.98 (1H, s, H-3), 5.66 (1H, d, $J$=9.8 Hz, H-3′), 2.08 (3H, d, $J$=1.7 Hz, 5-$CH_3$), 1.44 (6H, s, 2′-$CH_3 \times 2$).

2-(2,2-Dimethyl-2*H*-chromen-6-ylamino)-6-methyl-1,4-benzoquinone (**10k**): Yield 31%. Violet needles from methanol, mp 117—118 °C. *Anal.* Calcd for $C_{18}H_{17}NO_3$: C, 73.20; H, 5.80; N, 4.74. Found: C, 73.19; H, 5.72; N, 4.65. MS *m/z*: 295 ($M^+$). $^1$H-NMR ($CDCl_3$) $\delta$: 7.09 (1H, br s, NH), 6.90 (1H, dd, $J$=8.3, 2.7 Hz, H-7′), 6.82 (1H, d, $J$=2.7 Hz, H-5′), 6.75 (1H, d, $J$=8.3 Hz, H-8′), 6.49 (1H, sextet, $J$=2.5, 1.5 Hz, H-5), 6.26 (1H, d, $J$=9.8 Hz, H-4′), 5.93 (1H, d, $J$=2.5 Hz, H-3), 5.65 (1H, d, $J$=9.8 Hz, H-3′), 2.06 (3H, d, $J$=1.5 Hz, 6-$CH_3$), 1.44 (6H, s, 2′-$CH_3 \times 2$).

**Pyranocarbazolequinones 2, 3, and 5** A mixture of a chromenylaminobenzoquinone **9i**, **9j**, or **9k** (12 mg, 0.04 mmol) and $Pd(OAc)_2$ (9 mg, 0.04 mmol) in AcOH (5 ml) was refluxed for 4 min under an argon atmosphere. The same work-up as described above for **1a**—**g** afforded the corresponding **2**, **3**, and **5**. Compounds **2** and **3** were shown to be identical (IR, $^1$H-NMR, MS, and co-TLC) with natural pyrayaquinone-A and -B,[1c] respectively.

2,2,7-Trimethyl-2*H*,10*H*-pyrano[2,3-*b*]carbazole-6,9-quinone (pyrayaquinone-A) (**2**): Yield 78%. Brown crystals, mp 228 °C (dec.) [lit.[1c] mp 222 °C (dec.); lit.[3a] mp 220—222 °C]. High-resolution MS *m/z*: Calcd for $C_{18}H_{15}NO_3$: 293.1051. Found: 293.1052. IR $\nu_{max}^{CHCl_3}$ cm$^{-1}$: 1660, 1645, 1630, 1605. MS *m/z*: 293 ($M^+$), 279, 278, 250, 236, 222, 210. $^1$H-NMR ($CDCl_3$) $\delta$: 8.98 (1H, br s, NH), 7.79 (1H, s, H-5), 6.81 (1H, s, H-11), 6.48 (1H, d, $J$=10.0 Hz, H-4), 6.46 (1H, q, $J$=1.5 Hz, H-8), 5.72 (1H, d, $J$=10.0 Hz, H-3), 2.16 (3H, d, $J$=1.5 Hz, 7-$CH_3$), 1.48 (6H, s, 2-$CH_3 \times 2$).

3,3,8-Trimethyl-3*H*,11*H*-pyrano[3,2-*a*]carbazole-7,10-quinone (pyrayaquinone-B) (**3**): Yield 50%. Brown crystals, mp 248 °C (dec.) [lit.[1c] mp 244 °C (dec.); lit.[3a,b] mp 242 °C]. High-resolution MS *m/z*: Calcd for $C_{18}H_{15}NO_3$: 293.1051. Found: 293.1052. IR $\nu_{max}^{CHCl_3}$ cm$^{-1}$: 1665, 1660, 1645, 1610. $^1$H-NMR ($CDCl_3$) $\delta$: 9.26 (1H, br s, NH), 7.94 (1H, d, $J$=8.8 Hz, H-6), 6.86 (1H, d, $J$=8.8 Hz, H-5), 6.60 (1H, d, $J$=9.8 Hz, H-1), 6.44 (1H, q, $J$=1.5 Hz, H-9), 5.70 (1H, d, $J$=9.8 Hz, H-2), 2.14 (3H, d, $J$=1.5 Hz, 8-$CH_3$), 1.48 (6H, s, 3-$CH_3 \times 2$).

2,2,9-Trimethyl-2*H*,6*H*-pyrano[3,2-*b*]carbazole-7,10-quinone (**5**): Yield 50%. Brown crystals, mp 252 °C (dec.). High-resolution MS *m/z*: Calcd for $C_{18}H_{15}NO_3$: 293.1051. Found: 293.1052. $^1$H-NMR ($CDCl_3$) $\delta$: 9.13 (1H, br s, NH), 7.59 (1H, s, H-11), 7.05 (1H, s, H-5), 6.46 (1H, q, $J$=1.7 Hz, H-8), 6.43 (1H, d, $J$=9.8 Hz, H-4), 5.81 (1H, d, $J$=9.8 Hz, H-3), 2.15 (3H, d, $J$=1.7 Hz, 9-$CH_3$), 1.45 (6H, s, 2-$CH_3 \times 2$).

**2-Methylcarbazole-1,4-quinones 6a—g** In the same manner as for **1a**—**g**, the $Pd(OAc)_2$ treatment of **10a**—**g** (0.5 mmol) afforded the corresponding **6a**—**g**.

2-Methylcarbazole-1,4-quinone (**6a**): Yield 64%. Red flakes, mp 237—239 °C (dec.). *Anal.* Calcd for $C_{13}H_9NO_2$: C, 73.92; H, 4.30; N, 6.63. Found: C, 73.99; H, 4.04; N, 6.45. MS *m/z*: 211 ($M^+$). $^1$H-NMR (DMSO-$d_6$) $\delta$: 9.08 (1H, br s, NH), 8.20 (1H, dt, $J$=5.0, 1.0 Hz, H-5), 7.54—7.22 (3H, m, H-6, -7, and -8), 6.55 (1H, q, $J$=1.7 Hz, H-3), 2.14 (3H, d, $J$=1.7 Hz, 2-$CH_3$). $^{13}$C-NMR ($CDCl_3$+DMSO-$d_6$) $\delta$: 183.3 (s), 180.2 (s), 143.9 (s), 137.8 (s), 135.6 (s), 134.9 (d, C-3), 126.2 (d), 123.7 (d), 123.3 (s), 121.8 (d), 115.8 (s), 113.7 (d), 15.0 (q, 2-$CH_3$).

2,6-Dimethylcarbazole-1,4-quinone (**6b**): Yield 61%. Red plates, mp 240—242 °C (dec.). *Anal.* Calcd for $C_{14}H_{11}NO_2$: C, 74.65; H, 4.92; N, 6.22. Found: C, 74.50; H, 4.78; N, 6.28. MS *m/z*: 255 ($M^+$). $^1$H-NMR (DMSO-$d_6$) $\delta$: 12.72 (1H, br s, NH), 7.76 (1H, dd, $J$=1.7, 0.5 Hz, H-5), 7.39 (1H, dd, $J$=8.5, 0.5 Hz, H-8), 7.18 (1H, dd, $J$=8.5, 1.7 Hz, H-7), 6.53 (1H, q, $J$=1.7 Hz, H-3), 2.40 (3H, s, 6-$CH_3$), 2.02 (3H, d, $J$=1.7 Hz, 2-$CH_3$). $^{13}$C-NMR (DMSO-$d_6$) $\delta$: 183.2 (s), 179.9 (s), 143.7 (s), 136.0 (s), 135.4 (s), 134.7 (d, C-3), 133.0 (s), 128.1 (d), 123.5 (s), 120.9 (d), 115.1 (s), 113.3 (d), 21.1 (q), 14.8 (q, 2-$CH_3$).

6-Chloro-2-methylcarbazole-1,4-quinone (**6c**): Yield 49%. Red prisms, mp 263—265 °C (dec.). *Anal.* Calcd for $C_{13}H_8ClNO_2$: C, 63.56; H, 3.28; N, 5.70. Found: C, 63.52; H, 3.29; N, 5.50. MS *m/z*: 247 ($M^+$ +2), 245 ($M^+$). $^1$H-NMR (DMSO-$d_6$) $\delta$: 12.97 (1H, br s, NH), 7.86 (1H, dd, $J$=2.0, 0.7 Hz, H-5), 7.50 (1H, dd, $J$=8.8, 0.7 Hz, H-8), 7.34 (1H, dd, $J$=8.8, 2.0 Hz, H-7), 6.54 (1H, q, $J$=1.7 Hz, H-3), 2.03 (3H, d, $J$=1.7 Hz, 2-$CH_3$). $^{13}$C-NMR (DMSO-$d_6$) $\delta$: 182.6 (s), 179.7 (s), 144.0 (s), 136.4 (s), 135.9 (s), 134.6 (d, C-3), 128.2 (s), 126.2 (d), 123.9 (s), 120.5 (d), 115.3 (d), 114.8 (s), 14.9 (q, 2-$CH_3$).

6-Fluoro-2-methylcarbazole-1,4-quinone (**6d**): Yield 83%. Orange flakes, mp 257—260 °C (dec.). *Anal.* Calcd for $C_{13}H_8FNO_2$: C, 68.12; H, 3.52; N, 6.11. Found: C, 68.07; H, 3.52; N, 6.11. MS *m/z*: 229 ($M^+$). $^1$H-NMR (DMSO-$d_6$) $\delta$: 12.94 (1H, br s, NH), 7.60 (1H, ddd, $J$=9.3, 2.4, 0.5 Hz, H-5), 7.52 (1H, ddd, $J$=9.3, 4.6, 0.5 Hz, H-8), 7.22 (1H, td, $J$=9.3, 2.4 Hz, H-7), 6.53 (1H, q, $J$=1.7 Hz, H-3), 2.03 (3H, d, $J$=1.7 Hz, 2-$CH_3$). $^{13}$C-NMR ($CDCl_3$+DMSO-$d_6$) $\delta$: 182.9 (s), 179.9 (s), 164.2 and 154.6 (each s, fluorine-coupled carbon), 144.2 (s), 136.9 (s), 134.8 (d, C-3), 134.3 (s), 123.7 and 123.2 (each s, fluorine-coupled carbon), 115.7 and 115.3 (each d, fluorine-coupled carbon), 115.7 (s), 115.7 and 114.6 (each d, fluorine-coupled carbon), 106.4 and 105.4 (each d, fluorine-coupled carbon), 14.9 (q, 2-$CH_3$).

6-Methoxy-2-methylcarbazole-1,4-quinone (**6e**): Yield 46%. Orange needles, mp 280—281 °C (dec.). *Anal.* Calcd for $C_{14}H_{11}NO_3$: C, 69.70; H, 4.59; N, 5.80. Found: C, 69.67; H, 4.63; N, 5.70. MS *m/z*: 241 ($M^+$). $^1H$-NMR (DMSO-$d_6$) $\delta$: 12.70 (1H, br s, NH), 7.36 (1H, dd, $J$=9.0, 0.7 Hz, H-8), 7.34 (1H, d, $J$=2.4 Hz, H-5), 6.94 (1H, dd, $J$=9.0, 2.4 Hz, H-7), 6.48 (1H, q, $J$=1.5 Hz, H-3), 3.78 (3H, s, 6-$OCH_3$), 1.99 (3H, d, $J$=1.5 Hz, 2-$CH_3$). $^{13}C$-NMR (DMSO-$d_6$) $\delta$: 183.5 (s), 179.4 (s), 158.8 (s), 144.0 (s), 139.1 (s), 134.7 (s), 134.1 (d, C-3), 122.4 (d), 117.4 (s), 116.1 (s), 115.1 (d), 95.0 (d), 55.3 (q), 14.9 (q, 2-$CH_3$).

7-Methoxy-2-methylcarbazole-1,4-quinone (**6f**): Yield 42%. Brown needled, mp 250—252 °C (dec.). *Anal.* Calcd for $C_{14}H_{11}NO_3$: C, 69.70; H, 4.59; N, 5.80. Found: C, 69.68; H, 4.71; N, 5.65. MS *m/z*: 241 ($M^+$). $^1H$-NMR (DMSO-$d_6$) $\delta$: 12.63 (1H, br s, NH), 7.84 (1H, d, $J$=9.5 Hz, H-5), 6.93 (1H, dd, $J$=9.5, 2.2 Hz, H-6), 6.90 (1H, d, $J$=2.2 Hz, H-8), 6.51 (1H, q, $J$=1.7 Hz, H-3), 3.81 (3H, s, 7-$OCH_3$), 2.03 (3H, d, $J$=1.7 Hz, 2-$CH_3$). $^{13}C$-NMR (DMSO-$d_6$) $\delta$: 183.1 (s), 179.7 (s), 156.8 (s), 143.9 (s), 135.5 (s), 134.8 (d, C-3), 132.9 (s), 124.1 (s), 117.6 (d), 115.3 (s), 114.7 (d), 101.5 (d), 55.3 (q), 14.9 (q, 2-$CH_3$).

8-Methoxy-2-methylcarbazole-1,4-quinone (**6g**): Yield 58%. Brown needles, mp 212—214 °C. *Anal.* Calcd for $C_{14}H_{11}NO_3$: C, 69.70; H, 4.59; N, 5.80. Found: C, 69.64; H, 4.56; N, 5.50. MS *m/z*: 241 ($M^+$). $^1H$-NMR (DMSO-$d_6$) $\delta$: 12.98 (1H, br s, NH), 7.54 (1H, dd, $J$=7.8, 1.0 Hz, H-5), 7.19 (1H, t, $J$=7.8 Hz, H-6), 6.89 (1H, dd, $J$=7.8, 1.0 Hz, H-7), 6.55 (1H, q, $J$=1.7 Hz, H-3), 3.93 (3H, s, 8-$OCH_3$), 2.03 (3H, d, $J$=1.7 Hz, 2-$CH_3$). $^{13}C$-NMR (DMSO-$d_6$) $\delta$: 183.2 (s), 179.5 (s), 147.4 (s), 144.0 (s), 135.3 (s), 134.4 (d, C-3), 128.5 (s), 124.7 (s), 124.6 (d), 116.1 (s), 113.6 (d), 105.9 (d), 55.4 (q), 14.9 (q, 2-$CH_3$).

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