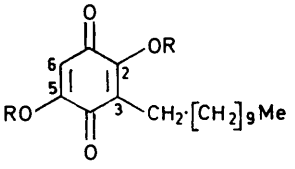
Benzoquinone Derivatives. Part I. Reactions of Primary Aliphatic Amines with Embelin (2,5-Dihydroxy-3-undecyl-1,4-benzoquinone) and Di-*O*-methylembelin

By **Balawant S. Joshi** * and **Venkatesh N. Kamat**, Ciba-Geigy Research Centre, Goregaon, Bombay 400063, India

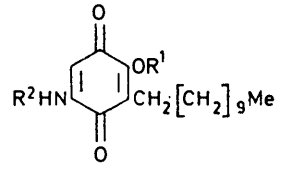
The reaction of embelin with some primary aliphatic amines has been reinvestigated. Embelin reacts with methylamine to give the 5-methylamino-derivative (2) or the quinone bismethylimine (9), depending on he conditions. 2-Hydroxy-5-methylamino-3-undecyl-1,4-benzoquinone 1-methylimine (11) is obtained by the reaction of di-*O*-methylembelin with methylamine. The products of condensation of several primary aliphatic amines with embelin and its di-*O*-methyl derivative have been characterized.

EMBELIN (1), the major chemical constituent of *Embelia ribes* Burn. and *Embelia tsjeriam* Cottam is reputed to possess anthelminthic activity.[1] We were interested in the preparation of some aliphatic amino-derivatives of embelin in order to investigate their pharmacological profiles. Primary aliphatic amines are known to react with 1,4-benzoquinones to give nuclear aminated quinones.[2-4]

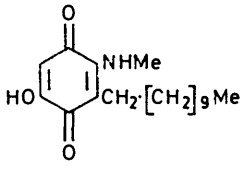
When embelin was heated in acetic acid with methylamine (2 mol. equiv.), a compound was obtained which on the basis of spectroscopic data could be formulated as (2) or (3). Its n.m.r. spectrum showed an olefinic proton signal at δ 5·2 and a doublet at 2·85 (3H, *J* 5 Hz, NH*Me*). In order to choose between the two structures, the monomethylamino derivative was *O*-acetylated; the product showed the ring olefinic proton signal at δ 5·4. Diacetylembelin (4), obtained by heating embelin with acetic anhydride,[5] showed a deshielded olefinic proton (δ 5·8 ⟶ 6·55), the shift being due to the paramagnetic anisotropic effect of the 5-acetoxy-group.[6-8] If the methylamino-derivative had structure (3), the *O*-acetyl derivative would be expected to show a similar downfield shift of the olefinic proton signal by about 0·7 p.p.m. The product is therefore assigned structure (2) and its acetyl derivative structure (5). The less hindered 5-hydroxy-group of embelin appears to be replaced first by methylamine. Alkaline hydrolysis of (2) gave embelin. Compound (2) was also the major product when embelin was heated with 6 mol. equiv. of methylamine in acetic acid or with 2 mol. equiv. of methylamine at 230° without solvent. Methylation of embelin (1) with a limited amount of diazomethane afforded 5-*O*-methylembelin; use of an excess of reagent gave the di-*O*-methyl derivative (6). The monomethyl ether formed an acetyl derivative, which showed an olefinic proton signal at δ 5·9. Treatment of 5-*O*-methylembelin with 2 mol. equiv. of methylamine in ethanol gave compound (2). Similar treatment of embelin gave a mixture from which only about 15% of (2) could be isolated. Nucleophilic displacement of halogeno, alkoxy-, or alkyl substituents from benzoquinones by alkylamines has been reported.[2,9-11] However, some alkoxy-hydroxytoluquinones do not undergo replacement of the hydroxy-substituent when treated with methylamine.[11] The formation of (2) from embelin therefore could be rationalized



(1) R = H
(4) R = Ac
(6) R = Me



	R^1	R^2
(2)	H	Me
(5)	Ac	Me
(10)	Me	Me
(14)	H	Et
(15)	H	$CH_2{\cdot}CH_2{\cdot}OMe$
(16)	H	Pr^n
(17)	H	Bu^n
(18)	H	$[CH_2]_4{\cdot}OH$
(19)	H	CH_2Ph
(20)	H	$CH_2{\cdot}CH_2Ph$



(3)

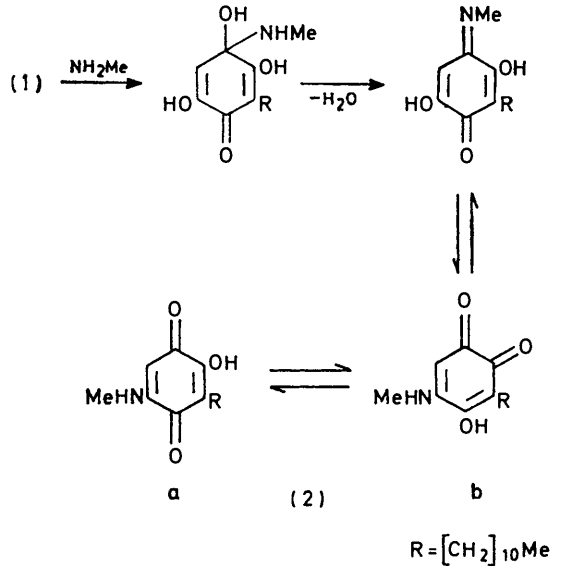
in terms of a 1,2-addition of methylamine, followed by elimination of water (Scheme 1).

Acetylation of embelin with acetic anhydride and pyridine afforded an unexpected product (7), identified on the basis of its u.v. ($\lambda_{max.}$ 243 nm), i.r. [$\nu_{max.}$ 1780 cm^{-1} (acetate)] and n.m.r. spectra [δ 8·63 (2H, d, d, *J* 6 and 1·5 Hz, pyridine α-protons), 7·25 (2H, d, d, *J* 6 and 1·5 Hz, β-protons), 2·5br (2H, ArCH_2), 2·3 (6H, s, 2- and 4-OAc), and 1·98 (6H, s, 1- and 5-OAc), 1·3 (18H, s), and 0·9 (3H, m)]. Its mass spectrum showed the molecular ion at *m/e* 541 and successive loss of four acetate units. Its formation may be explained by attack of the acylpyridinium cation on the unsubstituted position of the quinone ring in embelin, to give (8) as an intermediate.

When embelin was heated with 6 mol. equiv. or an excess of 33% methylamine in ethanol, the bismethylimine (9) was obtained, identified on the basis of elemental analysis and spectroscopic data. Its i.r. spectrum

[1] The Merck Index, Merck & Co. Inc., Rahway, New Jersey, 1968, p. 406.
[2] D. W. Cameron and P. M. Scott, *J. Chem. Soc.*, 1964, 5569.
[3] A. Hikosaka, *Bull. Chem. Soc. Japan*, 1970, **43**, 3928.
[4] W. K. Anslow and H. Raistrick, *Biochem. J.*, 1938, **32**, 803.
[5] R. Kaul, A. C. Ray, and S. Dutt, *J. Indian Chem. Soc.*, 1929, **6**, 577.
[6] J. A. Ballantine and C. T. Pillinger, *Tetrahedron*, 1967, **23**, 1961.
[7] R. E. Moore and P. J. Scheuer, *J. Org. Chem.*, 1966, **31**, 3272.
[8] H. Ogawa and S. Natori, *Chem. and Pharm. Bull. Japan*, 1968, **16**, 1709.
[9] J. Hoffmann, *Ber.*, 1901, **34**, 1558.
[10] O. Böters, *Ber.*, 1902, **35**, 1502.
[11] W. K. Anslow and H. Raistrick, *J. Chem. Soc.*, 1939, 1446.

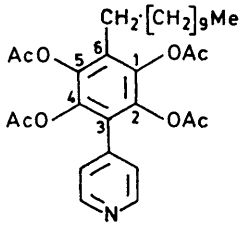
did not show any carbonyl bands and its n.m.r. spectrum exhibited signals at δ 9·17 (2H, OH, exchanged by D_2O),



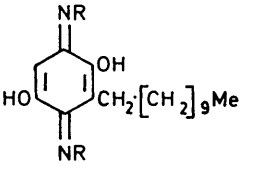
SCHEME 1

5·05 (1H, s, olefinic), and 3·15 (6H, s, =NMe). Compound (9) was also obtained by treating the monomethylamino-derivative (2) with an excess of methylamine in ethanol, or (in 15% yield) by heating embelin with an excess of methylamine at 200° without solvent.

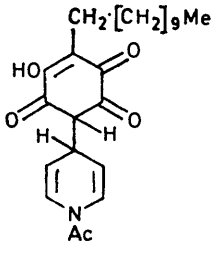
Kaul *et al.* obtained ' dimethylaminoembelin,' m.p. 216°, by heating embelin with an excess of dimethylamine



(7)



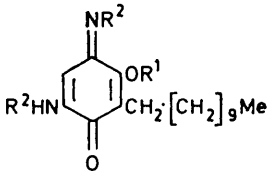
	R
(9)	Me
(21)	Et
(22)	$CH_2 \cdot CH_2 \cdot OMe$
(23)	Pr^n
(24)	Bu^n
(25)	$[CH_2]_4 \cdot OH$
(26)	CH_2Ph
(27)	$CH_2 \cdot CH_2Ph$



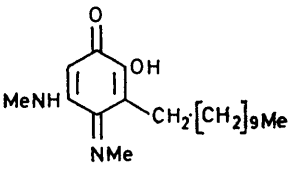
(8)

in methanol.[5] Heffter and Feuerstein reported the formation of ' methylaminoembelin,' m.p. 166·5°, by condensing embelin (then named embelic acid) with methylamine.[12] Rao and Venkateswarlu claim to have isolated compound (9), m.p. 167—168° (*cf.* our value of 248°), by heating embelin with 2 mol. equiv. of methylamine without solvent.[13] No proof was given for this formulation except elemental analysis. Under the conditions described by Rao and Venkateswarlu we isolated mainly compound (2), m.p. 164°, and, as a minor product, (9), m.p. 246—248°. The m.p.s of the compounds obtained by Heffter and by Rao appear to indicate structure (2), and the compound isolated by Kaul *et al.*, although its m.p. is lower, structure (9). The formation of (2) or (9) from embelin therefore appears to be solvent-dependent.

The bis-methylimine (9) is probably formed by two 1,2-additions of methylamine to the quinone carbonyl groups; its n.m.r. spectrum indicates that it exists predominantly in the tautomeric form illustrated rather than as the 2,5-bismethylamino-1,4-quinone.



	R^1	R^2
(11)	H	Me
(13)	Ac	Me
(28)	H	Et
(29)	H	$CH_2CH_2 \cdot OMe$
(30)	H	Pr^n
(31)	H	Bu^n
(32)	H	$[CH_2]_4 \cdot OH$
(33)	H	CH_2Ph
(34)	H	$CH_2 \cdot CH_2Ph$



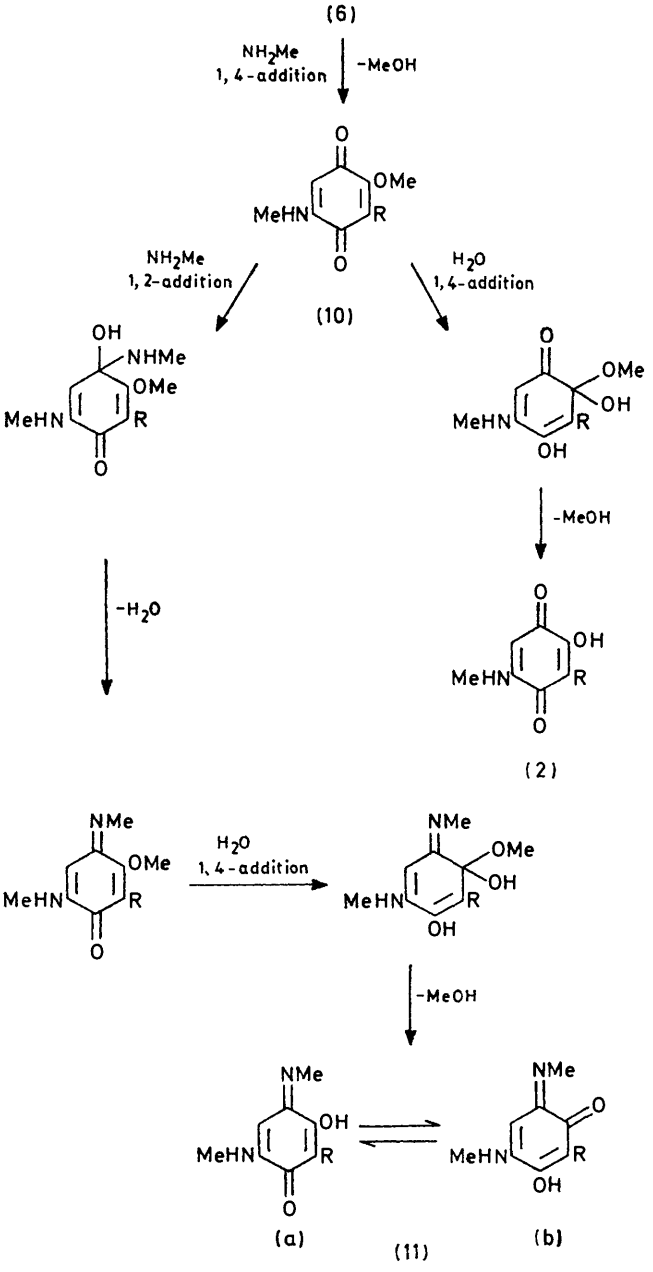
(12)

Methylation of compound (2) with diazomethane gave the methyl ether (10). Treatment of di-*O*-methylembelin with an excess of methylamine in ethanol at 25 or 80° afforded a bismethylamino-derivative, m.p. 152°, isomeric with (9). Its i.r. [$\nu_{max.}$ 3320 (NH), 3280 (OH), and 1640 and 1620 cm^{-1} (C:O)] and n.m.r. spectra [δ 6·7br (1H, NH, exchanged by D_2O), 5·22 (1H, s, olefinic), 3·21 (3H, s, =NMe), and 2·88 (3H, d, *J* 5 Hz, $-NHMe$; becomes a singlet on addition of D_2O)] suggested the structure (11) or (12). The singlet at δ 3·21 and the doublet at 2·88 clearly show that the methyl groups are attached to a tertiary and a secondary nitrogen atom, respectively. In the spectrum of compound (9) the six-proton singlet at δ 3·15 is ascribed to the two methylimino-groups. Similar doublet *N*-methyl peaks in the spectra of methylamino-derivatives have been observed for some alkylaminobenzoquinones.[14]

A number of methoxy-benzoquinones and -toluquinones have been condensed with methylamine to

[12] A. Heffter and W. Feuerstein, *Arch. Pharm.*, 1900, **238**, 15.
[13] T. V. P. Rao and V. Venkateswarlu, *Tetrahedron*, 1964, **20**, 969.
[14] K. Yoshihira, S. Sakaki, H. Ogawa, and S. Natori, *Chem. and Pharm. Bull. Japan*, 1968, **16**, 2383.

afford bismethylaminobenzoquinones by displacement of the methoxy- and methyl groups.[11] It is difficult to choose between the structures (11) and (12) from the present evidence; however the formulation (11) is preferred for the following reasons: (*a*) one of the probable modes of the formation of the compound is as shown in



SCHEME 2 R = $[CH_2]_{10}Me$

Scheme 2; (*b*) addition of the second methylamino-group at the less hindered carbonyl group would be expected; (*c*) the compound gives no colouration with ion(III) chloride.

* U.v., i.r., n.m.r., and mass spectral data of all products are available as Supplementary Publication No. SUP 21223 (4 pp.). For details of Supplementary Publications see Notice to Authors No. 7 in *J.C.S. Perkin I*, 1974, Index issue.

Compound (11) was also obtained by reaction of (10) with methylamine in ethanol. In order to identify the intermediates formed in this reaction, di-*O*-methylembelin (6) was treated with methylamine at low temperature. The mixture obtained contained predominantly (11), and also compounds (2) and (10). Hydrolysis of compound (11) with 5N-sulphuric acid gave 2-hydroxy-5-methylamino-3-undecyl-1,4-benzoquinone (2). Acetylation of (11) gave a monoacetyl derivative (13), whose n.m.r. spectrum showed an olefinic proton signal at δ 5·5.

The generality of the reactions described above has been shown by reactions of embelin (1) and di-*O*-methylembelin (6) with various aliphatic amines. Thus the condensation of embelin with ethyl-, β-methoxyethyl-, propyl-, butyl-, 4-hydroxybutyl-, benzyl-, and phenethyl-amine in acetic acid afforded compounds (14)—(20), respectively (Tables 1 and 4). When the reaction of embelin was carried out with an excess of any of the above-mentioned amines in ethanol, bisalkylimines (21)—(27), respectively, were obtained (Tables 2 and 5). Rao and Venkateswarlu report the production of the diimine (26), m.p. 156—157°, from the reaction of embelin with benzylamine (2 mol. equiv.) in acetic acid.[13] However, the m.p. they report appears to correspond to the amino-quinone (19). Di-*O*-methylembelin (6) reacted with these amines to afford compounds (28)—(34), respectively (Tables 3 and 6).*

The mass spectra of the alkylamino-quinones can be interpreted in a similar way to those of long-chain alkylated hydroxy-benzoquinones.[15]

EXPERIMENTAL

U.v. and i.r. spectra were determined with Beckman DK-2A and Perkin-Elmer Infracord spectrophotometers. N.m.r. spectra were taken with a Varian A-60 spectrophotometer (tetramethylsilane as internal reference). Mass spectra were taken with an Atlas CH-7 spectrometer by use of the direct inlet system.

Isolation of Embelin (1).—The dried berries of *Embelia tsjeriam* Cottam (5 kg) were extracted with hot hexane (4 × 15 l). Evaporation, and crystallization of the residue from methanol gave embelin as orange plates (83 g), m.p. 146°, affording a red-brown colouration with alcoholic iron(III) chloride; $\lambda_{max.}$ (EtOH) 290 nm (log ε 4·32); $\nu_{max.}$ (Nujol) 3300 (OH), and 1640 and 1620 cm^{-1} (chelated carbonyls); δ [$(CD_3)_2SO$] 5·8 (1H, s, 6-H), 2·4br (2H, t, $ArCH_2$), 1·3 (18H, s, CH_2), and 0·9 (3H, m, Me); *m/e* 294 (M^+, 40%), 155 (30), 154 (100), 153 (20), and 142 (15).

5-O-*Methylembelin*.—Embelin (5 g) was dissolved in ether (150 ml) and ethereal diazomethane [from nitrosomethylurea (6 g)] was added. Removal of solvent and crystallization from hexane afforded 2-*hydroxy*-5-*methoxy*-3-*undecyl*-1,4-*benzoquinone* as yellow needles (2·0 g), m.p. 95—96°, giving a violet colouration with iron(III) chloride; $\nu_{max.}$ 3380 (OH), 1640, and 1600 cm^{-1}; δ ($CDCl_3$) 7·45 (1H, s, OH, exch. by D_2O), 5·9 (1H, s, 6-H), and 3·9 (3H, s, OMe) (Found: C, 70·4; H, 9·4. $C_{18}H_{28}O_4$ requires C, 70·1; H, 9·2%), M^+, 308. The O-*acetate* formed lemon-yellow plates, m.p. 78° (Found: C, 68·5; H, 8·8. $C_{20}H_{30}O_5$ requires C, 68·5; H, 8·6%).

[15] H. Ogawa, S. Sakaki, K. Yoshihira, and S. Natori. *Tetrahedron Letters*, 1968, 1387.

2,5-*Di*-O-*methylembelin* (6).—Embelin (3 g) dissolved in ether (100 ml) was treated with an excess of diazomethane in ether and left overnight. Removal of solvent and crystallization from aqueous methanol afforded the diether (6) (2·5 g), m.p. 58°; $\lambda_{max.}$ (EtOH) 288 nm (log ε 4·13); $\nu_{max.}$ (Nujol) 1670 and 1640 cm^{-1} (quinone); δ ($CDCl_3$) 5·75 (1H, s, 6-H), 4·1 (3H, s, OMe), 3·85 (3H, s, OMe), 2·45br (2H, t, $ArCH_2$), 1·3 (18H, s), and 0·9 (3H, m); *m/e* 322 (M^+, 100%), 307 (5), 279 (10), 275 (7), 183 (40), 182 (40), 169 (50), and 167 (60).

Di-O-*acetylembelin* (4).—Embelin (500 mg) was refluxed with acetic anhydride (10 ml) for 1 h, and poured on crushed ice. The precipitate was collected and crystallized from aqueous methanol to afford the diacetate (4) (400 mg) as pale yellow needles, m.p. 59° (lit.,[5] 54°); $\lambda_{max.}$ (EtOH) 263 nm (log ε 4·1); $\nu_{max.}$ (Nujol) 1800 and 1780 (acetate), and 1680 and 1630 cm^{-1} (quinone); δ ($CDCl_3$) 6·55 (1H, s, 6-H), 2·4 (2H, m), 2·32 (6H, s, AcO), 1·3 (18H, s), and 0·9 (3H, m) (Found: C, 66·3; H, 8·3. Calc. for $C_{21}H_{30}O_6$: C, 66·6; H, 8·0%).

1,2,4,5-*Tetra-acetoxy*-3-*pyridyl*-6-*undecylbenzene* (7).—A solution of embelin (500 mg) in pyridine (5 ml) and acetic anhydride (10 ml) was kept overnight at 25°, then diluted with crushed ice, and extracted with methylene chloride. The organic layer was washed with 5% hydrochloric acid, aqueous 5% sodium hydrogen carbonate, and water, then evaporated. Crystallization of the residue from aqueous methanol gave *prisms* (300 mg), m.p. 115°; $\lambda_{max.}$ (EtOH) 243 nm (log ε 4·2); $\nu_{max.}$ (Nujol) 1780 (acetate) and 1600 cm^{-1}; for n.m.r. data see Discussion section; *m/e* 541 (M^+, <1%), 499 (5), 457 (16), 415 (25), 373 (100), 274 (25), 259 (20), and 233 (100) (Found: C, 66·2; H, 7·5; N, 2·7. $C_{30}H_{39}NO_8$ requires C, 66·5; H, 7·2; N, 2·6%).

2-*Hydroxy*-5-*methylamino*-3-*undecyl*-1,4-*benzoquinone* (2).—(*a*) A mixture of embelin (2·94 g), methylamine (3 ml; 33% ethanolic solution), and glacial acetic acid (40 ml) was heated at 100° for 3 h. The crystalline residue which separated on cooling was collected and recrystallized from acetic acid to afford pinkish red *needles* (2) (2·2 g), giving a dark violet colouration with alcoholic iron(III) chloride.

(*b*) Embelin (2·94 g) and methylamine (3 ml; 33% ethanolic solution) were heated under reflux at 230° for 30 min. The mixture was poured into dilute hydrochloric acid and the precipitate collected. Crystallization from acetic acid gave (2) (1·4 g). T.l.c. of the mother liquor showed spots corresponding to compounds (9) and (11).

(*c*) 5-*O*-Methylembelin (120 mg) in ethanol (15 ml) was refluxed with methylamine (80 mg) for 1 h. The precipitate was collected and crystallized from acetic acid to give (2) (80 mg).

2-*Acetoxy*-5-*methylamino*-3-*undecyl*-1,4-*benzoquinone* (5).—A solution of compound (2) (300 mg) in pyridine (3 ml) and acetic anhydride (1·5 ml) was left overnight, then poured on crushed ice. The precipitate crystallized from aqueous methanol to give brownish *needles* (200 mg), m.p. 78°; $\lambda_{max.}$ (EtOH), 214, 289, and 490 nm (log ε 4·3, 4·0, and 3·4); $\nu_{max.}$ (Nujol) 3260 (NH), 1760 (acetate), and 1660 and 1658 cm^{-1} (quinone); δ ($CDCl_3$) 5·9br (1H, NH, exch. by D_2O), 5·4 (1H, s, 6-H), 2·9br (3H, NH*Me*; becomes singlet on addition of D_2O), 2·38 (3H, s, AcO), 2·4 (2H, m) 1·3 (18H, s), and 0·9 (3H, m) (Found: C, 69·2; H, 8·9; N, 4·0. $C_{20}H_{31}NO_4$ requires C, 68·7; H, 8·9; N, 4·0%); M^+, 349.

2-*Methoxy*-5-*methylamino*-3-*undecyl*-1,4-*benzoquinone* (10).—To a solution of compound (2) (300 mg) in methanol (10 ml) and ether (40 ml), an excess of ethereal diazomethane was added and the mixture was left overnight. Removal of solvent and crystallization from aqueous methanol afforded maroon *plates* (10) (170 mg), m.p. 90°; $\lambda_{max.}$ (EtOH) 312 and 500 nm (log ε 4·1 and 3·2); $\nu_{max.}$ (Nujol) 3300 (NH) and 1650 and 1640 cm^{-1} (quinone); δ ($CDCl_3$) 6·0br (1H, NH, exch. by D_2O), 5·27 (1H, s, 6-H), 4·15 (3H, s, OMe), 2·85 (3H, d, *J* 5 Hz, NH*Me*; becomes singlet on addition of D_2O), 2·4 (2H, m), 1·3 (18H, s), and 0·9 (3H, m) (Found: C, 71·0; H, 9·9; N, 4·6. $C_{19}H_{31}NO_3$ requires C, 71·0; H, 9·7; N, 4·3%).

2,5-*Dihydroxy*-3-*undecyl*-1,4-*benzoquinone* 1,4-*Bismethylimine* (9).—(*a*) A mixture of embelin (2·94 g), methylamine

TABLE 1

Spectral data for 5-alkylamino-2-hydroxy-3-undecyl-1,4-benzoquinones

Compound	$\lambda_{max.}$(EtOH)/nm (log ε)	$\nu_{max.}$ (Nujol)/cm^{-1}	δ (p.p.m.) ($CDCl_3$)	*m/e*
(2)	313, 500 (4·23, 3·1)	3300 (NH), 1658 (C=O)	5·2 (1H, s), 2·85 (3H, d, *J* 5 Hz, NH*Me*; s on addition of D_2O)	307 (M^+, 100%), 167 (86), 166 (80), 154 (25), 138 (25)
(15)	315, 500 (4·27, 3·16)	3300, 1640	6·5br (1H, NH, exch. D_2O), 5·4 (1H, s), 3·2 (2H, d, *J* 6 Hz, $NH{\cdot}CH_2$), 3·42 (3H, s, OMe)	351 (M^+, 80%), 306 (50), 211 (40), 210 (100), 198 (15), 166 (60)
(20)	315, 500 (4·24, 3·15)	3360, 3300, 1660	7·25 (5H, s, Ph), 6·5br (1H, exch. D_2O), 5·4 (1H, s), 3·35 (2H, m, $ArCH_2$), 3·0 (2H, q, $NH{\cdot}CH_2$)	397 (M^+, 70%), 306 (100), 257 (30), 256 (60), 166 (90), 152 (20)

TABLE 2

Spectral data for 2,5-dihydroxy-3-undecyl-1,4-benzoquinone bisalkylimines

Compound	$\lambda_{max.}$(EtOH)/nm (log ε)	$\nu_{max.}$(Nujol)/cm^{-1}	δ (p.p.m.) ($CDCl_3$)	*m/e*
(9)	216, 340infl., 350 (4·46, 4·45, 4·48)	3180, 1590, 1510	9·17br (2H, exch. D_2O), 5·05 (1H, s), 3·15 (6H, s, =NMe)	320 (M^+, 30%), 193 (15), 180 (45), 179 (100), 151 (15)
(22)	215, 350 (4·47, 4·5)	3180, 1600, 1520	8·8br (2H, exch. D_2O), 5·2 (1H, s), 3·65 (8H, s, $W_{\frac{1}{2}}$ 2 Hz, $=N{\cdot}CH_2{\cdot}CH_2{\cdot}OMe$), 3·4 (6H, s, OMe)	408 (M^+, 100%), 363 (30), 361 (30), 349 (25), 331 (20), 268 (30), 267 (98)
(27)	255, 355 (3·89, 4·46)	3180, 1580, 1540	9·17br (2H, exch. D_2O), 7·25 (10H, s, Ph), 4·8 (1H, s), 3·55 (4H, t, CH_2Ph), 3·0 (4H, t, $=N{\cdot}CH_2$)	500 (M^+, 55%), 409 (60), 407 (100), 359 (80)

TABLE 3

Spectral data for 5-alkylamino-2-hydroxy-3-undecyl-1,4-benzoquinone 1-alkylimines

Compound	$\lambda_{max.}$(EtOH)/nm (log ε)	$\nu_{max.}$(Nujol)/cm^{-1}	δ (p.p.m.) ($CDCl_3$)	*m/e*
(11)	216, 342 (4·42, 4·38)	3320, 3280, 1640, 1620, 1590	6·7br (1H, exch. D_2O), 5·22 (1H, s), 3·21 (3H, s, =NMe), 2·88 (3H, d, *J* 5 Hz, NH*Me*; s on addition of D_2O)	320 (M^+, 100%), 180 (30), 179 (100), 151 (30)
(29)	215, 343 (4·42, 4·42)	3320, 3250, 1650, 1625, 1570	6·8br (2H, exch. D_2O), 5·3 (1H, s), 3·65br (4H, s, NH·C*H*$_2$, =N·C*H*$_2$), 3·41 (3H, s, OMe), 3·37 (3H, s, OMe), 3·1—3·6 (4H, m, C*H*$_2$)	408 (M^+, 40%), 376 (100), 363 (45), 331 (60), 268 (5), 267 (15), 235 (15)
(34)	345 (4·47)	3300, 3230, 1640, 1610, 1600, 1550	7·25 (10H, s, Ph), 6·7br (1H, exch. D_2O), 5·3 (1H, s), 3·75 (2H, t, *J* 7 Hz, =N·CH$_2$), 3·3 (2H, t, *J* 6 Hz, d on addition of D_2O, NH·C*H*$_2$), 2·95 (4H, m, C*H*$_2$Ph)	500 (M^+, 40%), 408 (100), 359 (10), 305 (15)

TABLE 4

5-Alkylamino-2-hydroxy-3-undecyl-1,4-benzoquinones †

Compound	Method of prep.†	Yield (%)	M.p. (°C)	Formula	Found (%) C	Found (%) H	Found (%) N	Required (%) C	Required (%) H	Required (%) N
(2)	*a*	75	164	$C_{18}H_{29}NO_3$	70·5	9·8	4·4	70·3	9·5	4·6
	b	15								
(14)	*b*	37	120	$C_{19}H_{31}NO_3$	71·1	9·9	4·6	71·0	9·7	4·4
(15)	*a*	65	105	$C_{20}H_{33}NO_4$	68·7	9·7	4·7	68·3	9·5	4·0
(16)	*a*	54	100	$C_{20}H_{33}NO_3$	71·5	10·2	4·7	71·6	9·9	4·2
	b	6								
(17)	*a*	65	105	$C_{21}H_{35}NO_3$	72·6	10·1	4·3	72·2	10·1	4·0
	b	18								
(18)	*a*	65	84	$C_{21}H_{35}NO_4$	69·1	9·5	3·8	69·0	9·6	3·8
	b	10								
(19)	*a*	70	160	$C_{24}H_{23}NO_3$	75·5	9·0	3·9	75·2	8·7	3·7
(20)	*a*	75	138	$C_{25}H_{35}NO_3$	75·3	9·0	3·4	75·5	8·9	3·5

† Embelin was refluxed with the appropriate amine (2 mol. equiv.) for 3 h; *a*, in glacial acetic acid; *b*, in ethanol.

TABLE 5

2,5-Dihydroxy-3-undecyl-1,4-benzoquinone 1,4-bisalkylimines

Compound	Method of prepn.†	Yield (%)	M.p. °(C)	Formula	Found (%) C	Found (%) H	Found (%) N	Required (%) C	Required (%) H	Required (%) N
(9)	*a*	56	248	$C_{19}H_{32}N_2O_2$	71·3	10·3	8·8	71·2	10·1	8·7
	b	15								
(21)	*a*	40	235	$C_{21}H_{36}N_2O_2$	72·6	10·7	8·3	72·4	10·4	8·0
(22)	*a*	20	200	$C_{23}H_{40}N_2O_4$	67·7	10·1	6·8	67·6	9·9	6·9
(23)	*a*	66	215	$C_{23}H_{40}N_2O_2$	73·7	11·1	7·7	73·4	10·7	7·4
	b	30								
(24)	*a*	75	210	$C_{25}H_{44}N_2O_2$	74·5	11·3	7·1	74·2	11·0	6·9
	b	40								
(25)	*a*	50	138	$C_{25}H_{44}N_2O_4$	68·6	10·3	6·7	68·8	10·2	6·4
(26)	*a*	85	230	$C_{31}H_{40}N_2O_2$	78·8	8·8	6·3	78·8	8·5	5·9
(27)	*a*	75	185	$C_{33}H_{44}N_2O_2$	79·1	9·2	5·6	79·2	8·9	5·6

[a] Embelin was refluxed with the appropriate amine (6 mol. equiv.) for 3 h in ethanol. [b] Embelin was heated at 200° with the appropriate amine (6 mol. equiv.) for 3 h.

TABLE 6

5-Alkylamino-2-hydroxy-3-undecyl-1,4-benzoquinone 1-alkylimines †

Compound	Yield (%)	M.p. (°C)	Formula	Found (%) C	Found (%) H	Found (%) N	Required (%) C	Required (%) H	Required (%) N
(11)	65	152	$C_{19}H_{32}N_2O_2$	71·6	10·3	8·7	71·2	10·1	8·7
(28)	40	107	$C_{21}H_{36}N_2O_2$	72·6	10·6	8·3	72·4	10·4	8·0
(29)	48	52	$C_{23}H_{40}N_2O_4$	67·7	10·1	6·8	67·6	9·9	6·9
(30)	25	72	$C_{23}H_{40}N_2O_2$	73·4	10·9	7·6	73·4	10·7	7·4
(31)	50	82	$C_{25}H_{44}N_2O_2$	74·4	11·2	7·3	74·2	11·0	6·9
(32)	45	83	$C_{25}H_{44}N_2O_4$	68·8	10·3	6·7	68·8	10·2	6·4
(33)	81	110	$C_{31}H_{40}N_2O_2$	78·5	8·7	6·1	78·8	8·5	5·9
(34)	50	75	$C_{33}H_{44}N_2O_2$	79·3	9·2	5·8	79·2	8·9	5·6

† Di-*O*-methylembelin was refluxed with the appropriate amine (6 mol. equiv.) for 3 h in ethanol.

(10 ml; 33% ethanolic solution), and ethanol (90 ml) was heated at 100° for 3 h. The precipitate obtained on cooling was collected and crystallized from ethyl acetate to afford dark blue *needles* (9) (1·8 g). The violet alcoholic solution became brown on addition of iron(III) chloride.

(*b*) A mixture of compound (2) (90 mg), methylamine (1 ml; 33% ethanolic solution), and ethanol (3 ml) was heated at 100° for 1 h, then cooled. The solid was collected and crystallized from ethyl acetate to afford dark blue needles (27 mg), identical with compound (9) obtained in (*a*) (mixed m.p., t.l.c., and i.r. spectra).

2-Hydroxy-5-methylamino-3-undecyl-1,4-benzoquinone 1-Methylimine (11).—(*a*) A solution of di-*O*-methylembelin (6) (1·2 g) in ethanol (20 ml) and methylamine (4 ml; 33% ethanolic solution) was kept at 25° for 20 min. The crystalline precipitate which separated was collected and crystallized from methylene chloride–methanol to afford violet *plates* (11) (0·8 g). The purple colour of a solution of (11) in ethanol faded to a pale colour on addition of iron(III) chloride.

(*b*) A mixture of compound (6) (800 mg), ethanolic 33% methylamine (2·5 ml), and ethanol (20 ml) was heated under reflux for 3 h. Crystallization of the product which separated on cooling gave (11) (500 mg).

(*c*) A mixture of compound (6) (320 mg), ethanolic 33% methylamine (100 mg), and ethanol (5 ml) was kept at 10° for 30 min and at 25° for 1 h. The crystalline precipitate was collected (170 mg) and recrystallized from methylene chloride–methanol to afford violet plates (11) (150 mg). The mother liquor was evaporated to dryness and the residue chromatographed on silica gel. Elution with benzene gave compounds (2) (50 mg), m.p. 162—164°, and (10) (35 mg), m.p. 89—90°, identified by mixed m.p., t.l.c., and i.r. spectral comparison.

2-Acetoxy-5-methylamino-3-undecyl-1,4-benzoquinone 1-Methylimine (13).—Compound (11) (300 mg) was refluxed with acetic anhydride (6 ml) for 2 h. The mixture was filtered and the filtrate poured on crushed ice; the solid product crystallized from aqueous methanol to give brick-red *needles* (100 mg), m.p. 68°; $\lambda_{max.}$ (EtOH) 216, 285, and 350 nm (log ε 4·41, 3·73, and 3·6); $\nu_{max.}$ 3280 (NH) and 1670 cm^{-1} (acetate); δ ($CDCl_3$) 5·9br (1H, NH), 5·5 (1H, s, 6-H), 3·1 (3H, s, =NMe), 2·9 (3H, d, *J* 5 Hz, NH*Me*), 2·4 (2H, m), 1·9 (3H, s, AcO), 1·3 (18H, s), and 0·9 (3H, m); *m/e* 362 (M^+, 90%), 320 (100), 207 (20), 179 (90), and 151 (50) (Found: C, 69·3; H, 10·0; N, 7·8. $C_{21}H_{34}N_2O_3$ requires C, 69·6; H, 9·5; N, 7·7%).

Acidic Hydrolysis of Compound (11).—Compound (11) (30 mg) was heated with 5N-sulphuric acid (15 ml) at 140° for 1·5 h. The mixture was diluted with crushed ice and the collected precipitate was washed with water and crystallized from methanol to afford pinkish needles of compound (2) (10 mg), m.p. 162—164°.

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