Carbon-13 and Proton Magnetic Resonance Spectra of 2,2-Dialkyl-5,5-dimethylcyclohexane-1,3-diones (2,2-Dialkyldimedones)[1]

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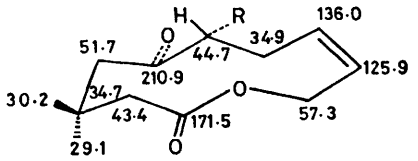
Proton and natural abundance carbon-13 Fourier transform n.m.r. spectra of ten 2,2-dialkyldimedones have been examined at 100 and 20 MHz respectively. Chemical shifts have been assigned in each case. In contrast to the significant long-range anisotropic shielding observed in the ^1H n.m.r. spectra of 2-benzyl compounds, there was a slight deshielding of the corresponding carbon nuclei in the ^{13}C spectra. The preparation of several new dialkyldimedones is also described.

In connection with a recent ^{13}C n.m.r. study of some 6-alkyl-3,3-dimethyl-5-oxodec-8-enolides (1) and several



(1)

^{13}C N.m.r. chemical shifts (δ) for (1). R = Me gives δ 16.8

other medium-ring and macrocyclic oxo-lactones,[2] we have examined the ^{13}C spectra of the title compounds (2) to evaluate the effect of conformational mobility as well as that of the two γ-carbonyl functions on the chemical shifts of the *gem*-dimethyl group. Moreover, as appreciable long-range shielding effects have been observed in the ^1H n.m.r. spectra of 2,2-dibenzylcyclohexane-1,3-diones, as well as the related spirotriketones (3) carrying aromatic groups,[3] we have compared the ^{13}C and ^1H n.m.r. spectra of these compounds.

RESULTS AND DISCUSSION

^{13}C *N.m.r. Spectra* (*Table* 1).—All the carbon resonances in compounds (2a—j) could be assigned unambiguously on the basis of proton noise-decoupled and single frequency off-resonance decoupled (SFORD) spectra. As dimedone (5,5-dimethylcyclohexane-1,3-dione) and its monoalkylated derivatives are present mainly in the enolic form and have poor solubility in most organic solvents, it is not possible to obtain the shielding parameters for the mono- or di-alkylated dimedones relative

[1] J. R. Mahajan, Abstracts, 29th Annual Meeting of 'SBPC,' *Ciência e Cultura*, 1977, **29** (supplement), 403.

[2] J. R. Mahajan and H. C. Araújo, *Canad. J. Chem.*, 1977, **55**, 3261.

[3] H. A. P. De Jongh and H. Wynberg, *Tetrahedron*, 1965, **21**, 515.

to the replacement of a hydrogen atom. However, shielding values for the replacement of one or two methyl groups, with the new substituents are given as a difference of chemical shift with respect to 2,2-dimethyldimedone (2a). Table 1 shows that the effect of substitution on the most affected C-2 is fairly additive for all the substituents examined. Although variations in the chemical shifts of other carbon atoms are small, the additive relationship seems to hold.

The *gem*-dimethyl group becomes equivalent in compounds carrying two identical substituents at C-2, thus revealing a rapid conformational equilibrium in these compounds, as has already been shown by De Jongh and Wynberg on the basis of ^{1}H n.m.r. spectra for (2a and g).[3,†] However, in the case of asymmetrical substitution at C-2, the two methyls are separated by 0.9—3.3 p.p.m., their chemical shifts being very close to the *gem*-dimethyl shieldings observed in compounds (1).[2] In a frozen conformation the geminal axial and equatorial methyl groups have shifts usually separated by *ca.* 8 p.p.m., as exemplified by 1,1,3-trimethylcyclohexane (CH_{3ax}, 25.5; CH_{3eq} 34.3 p.p.m.)[4a] and 3,3,5-trimethylcyclohexanol (CH_{3ax}, 25.7; CH_{3eq}, 33.1 p.p.m.).[5] The observed small difference in the present series is probably due to the conformational equilibrium, as in the case of symmetrically substituted compounds. The other possible cause for lowering the difference between the axial and equatorial methyl groups may be the lack of *syn*-axial hydrogen atoms at the γ-positions, which are assumed to be responsible for lowering the chemical shift of the axial methyl group.[4b,6] However, the reported shieldings for the axial (25.7) and equatorial (32.0) methyl carbons in 3,3,5-trimethylcyclohexanone [6] are almost identical with the corresponding values in the previous two examples, thus belying any effect of the removal of the *syn*-axial hydrogen atom in the present case. On the other hand,

TABLE 1

^{13}C Chemical shifts of 2,2-dialkyl-5,5-dimethylcyclohexane-1,3-diones (2a—j)

Compound		C-1–3 (s)	C-2 (s)	C-4–6 (t)	C-5 (s)	C-7 (q)	C-8 (q)	R^1	R^2
(2a)		210.0	60.3	51.0	30.5	28.3		R^1 = R^2 = CH_3: 22.1 (q)	
(2b)		208.9	64.2	51.5	30.6	29.1	27.9	CH_3: 18.5 (q)	C_AH_2·C_BH:C_CH_2 C_A, 41.3 (t); C_B, 132.3 (d) C_C, 119.1 (t)
	Δ	−1.1	3.9	0.5	0.1	0.8	−0.4		
(2c)		208.2	67.9	51.9	30.6	28.6		R^1 = R^2 = C_AH_2·C_BH:C_CH_2 C_A, 38.7 (t); C_B, 132.6 (d); C_C, 119.3 (t)	
	Δ	−1.8	7.6	0.9	0.1	0.3			
(2d)		208.6	63.3	50.8	30.6	29.1	27.1	CH_3: 23.6 (q)	C_AH_2·C_BH_2·C_CN C_A, 29.2 (t); C_B, 12.9 (t) C_C, 119.4 (s)
	Δ	−1.4	3.0	−0.2	0.1	1.3	−1.2		
(2e)		207.0	66.4	51.1	30.8	28.5		R^1 = R^2 = C_AH_2·C_BH_2·C_CN C_A, 29.1 (t); C_B, 12.7 (t); C_C, 118.6 (s)	
	Δ	−3.0	6.1	0.1	0.3	0.2			
(2f)		210.1	64.7	52.5	30.1	28.9	28.0	CH_3: 20.5 (q)	C_AH_2Ph C_A, 43.8 (t); C_q, 136.1 (s); C_o, 130.3; C_m, 128.2; C_p, 127.0
	Δ	0.1	4.4	1.5	−0.4	0.6	−0.3		
(2g)		211.2	70.2	54.3	29.2	28.6		R^1 = R^2 = C_AH_2Ph C_A, 44.5 (t); C_q, 136.4 (s); C_o, 130.9; C_m, 128.3; C_p, 127.1	
	Δ	1.2	9.9	3.3	−1.3	0.3			
(2h)		209.7	68.8	53.2	30.1	29.0	28.5	C_AH_2·C_BH:C_CH_2 C_A, 40.9 (t); C_B, 132.7 (d); C_C, 119.6 (t)	C_AH_2Ph C_A, 42.3 (t); C_q, 136.3 (s); C_o, 130.9; C_m, 128.2; C_p, 127.0
	Δ	−0.3 (−1.0)	8.5 (8.3)	2.2 (2.0)	−0.4	0.7	0.2		
(2i)		207.9	68.5	51.9	30.7	30.2	27.0	C_AH_2·C_BH_2·C_CN C_A, 27.3 (t); C_B, 12.9 (t) C_C, 119.4 (s)	C_AH_2Ph C_A, 44.7 (t); C_q, 133.8 (s); C_o, 130.1; C_m, 128.6; C_p, 127.8
	Δ	−2.1 (−1.3)	8.2 (7.4)	0.9 (1.3)	0.2	1.9	−1.3		
(2j)		207.4	67.6	5.12	30.7	30.2	26.9	C_AH_2·C_BH:C_CH_2 C_A, 42.2 (5); C_B, 130.1 (d) C_C, 120.6 (t)	C_AH_2·C_BH_2·C_CN C_A, 26.4 (t); C_B, 12.8 (t) C_C, 119.5 (s)
	Δ	−2.6 (−2.5)	7.3 (6.9)	0.2 (0.3)	0.2	1.9	−1.4		

s = Singlet; d = doublet; t = triplet; q = quartet, as observed in the SFORD spectra. For simplicity only the multiplicity of the quaternary carbon is marked in the aromatic nucleus. C_q, C_o, C_m, and C_p refer to the chemical shifts for the quaternary, *ortho*-, *meta*-, and *para*-C-atoms, respectively. Δ Indicates the difference with respect to compound (2a). The values in parentheses are the sum of the shielding parameters for the corresponding single substituents, as observed in this Table for the replacement of one of the 2-Me groups by the new substituent.

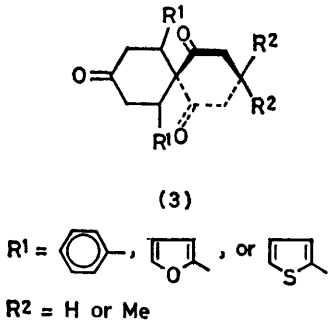
† However, these authors were unable to draw a definite conclusion regarding the presence of a rapid chair–chair equilibrium or that of an intermediate flexible form (*e.g.*, a twist-boat or flattened chair) on the basis of a variable temperature (−80 to 140 °C) study conducted with the spirotriketone (3; R^1 = Ph; R^2 = Me);[3] although our data do not resolve this matter, the arguments here presented remain valid.

[4] J. B. Stothers, 'Carbon-13 NMR Spectroscopy,' Academic Press, New York, 1972, (*a*) p. 64; (*b*) p. 66.

[5] L. F. Johnson and W. C. Jankowski, 'Carbon-13 NMR Spectra,' Wiley–Interscience, New York, 1972.

[6] J. B. Stothers and C. T. Tan, *Canad. J. Chem.*, 1974, **52**, 308.

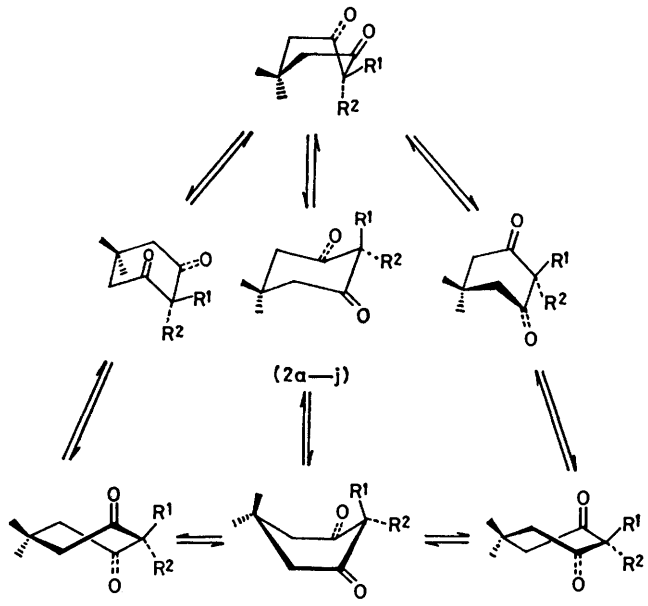
these three examples demonstrate that there is almost no change in the chemical shift of the axial methyl group on introducing an equatorial hydroxy or an oxo-group at the γ-position, while the same transformations produce a



successive shielding of 1.1 p.p.m. for the equatorial methyl carbon.

Although distinction between an axial and an equatorial substituent is not very clear in a conformationally flexible molecule, the conformer with the larger substituent in the equatorial position is evidently expected to predominate. Structures (2b, d, f, h—j) reflect this bias and the lower chemical shift has been assigned to the axial methyl group in this conformation or that *cis* to the larger substituent (R^2) in the twist boat form. Replacement of a single methyl group by a new substituent at C-2 affects the two methyls at C-5 to a different degree

Finally, we point out that, in sharp contrast to the ^1H n.m.r. spectra where appreciable long-range shielding has been observed for the protons of the *gem*-dimethyl group and the 4,6-methylenes in compounds carrying one



and especially two benzyl substituents (*vide infra*), there is no such effect observed in the ^{13}C spectra, in accordance with the previous observations.[7] On the contrary,

TABLE 2

^1H Chemical shifts (100 MHz) of 2,2-dialkyl-5,5-dimethylcyclohexane-1,3-diones (2a—j)

Compound	R^1	R^2	CH_2-4—6	CH_3-7 (s)	CH_3-8 (s)
(2a)	$R^1 = R^2 = CH_3$: 1.30 (s)		2.61 (s)	0.99	
(2c)	$R^1 = R^2 = CH_2{\cdot}C_2H_3$ CH_2, 2.50 (d, J 7 Hz); C_2H_3 4.96—5.80 (m)		2.59 (s)	0.99	
(2e)	$R^1 = R^2 = CH_2{\cdot}CH_2{\cdot}CN$: 2.20 (m, A_2B_2)		2.67 (s)	1.00	
(2g)	$R^1 = R^2 = CH_2Ph$ CH_2, 3.20 (s); Ph, 7.17 (m)		1.98 (s)	0.26	
(2b)	CH_3: 1.24 (s)	$CH_2{\cdot}C_2H_3$ CH_2, 2.50 (d, J 7 Hz); C_2H_3, 4.96—5.82 (m)	2.60 (ABq, J 15 Hz) ν_{AB} = 16 Hz	1.08	0.93
(2d)	CH_3: 1.39 (s)	$CH_2{\cdot}CH_2{\cdot}CN$: 2.20 (m, A_2B_2)	2.65 (ABq, J 15 Hz) ν_{AB} = 33 Hz	1.12	0.87
(2f)	CH_3: 1.26 (s)	CH_2Ph CH_2, 3.07 (s); Ph, 6.96—7.36 (m)	2.41 (ABq, J 16 Hz) ν_{AB} = 8 Hz	0.87	0.79
(2h)	$CH_2{\cdot}C_2H_3$ CH_2, 2.53 (d, J 7 Hz); C_2H_3, 4.95—5.88 (m)	CH_2Ph CH_2, 3.08 (s); Ph, 6.94—7.35 (m)	2.34 (ABq, J 16 Hz) ν_{AB} = 15 Hz	0.89	0.54
(2i)	$CH_2{\cdot}CH_2{\cdot}CN$: 2.11 (m, A_2B_2)	CH_2Ph CH_2, 3.05 (s); Ph, 6.82—7.40 (m)	2.62 (ABq, J 14 Hz) ν_{AB} = 31 Hz	1.06	0.80
(2j)	$CH_2{\cdot}C_2H_3$ CH_2, 2.50 (d, J 6 Hz); C_2H_3, 5.00—5.74 (m)	$CH_2{\cdot}CH_2{\cdot}CN$: 2.18 (m, A_2B_2)	2.61 (ABq, J 15 Hz) ν_{AB} = 36 Hz	1.16	0.82

m,A_2B_2 = A_2B_2 type multiplet; ABq = AB-type quartet; $\nu_{AB} = \sqrt{(1-4)(2-3)}$.

and in the opposite direction. In the case of two identical substituents these opposing effects cancel to leave a small (0.3 p.p.m.) deshielding of the *gem*-dimethyl group. However, when the two substituents at C-2 are different, the opposing influences are reinforced resulting in a larger separation (3.3 p.p.m.).

in the most affected 2,2-dibenzyldimedone (2g), there is a slight deshielding of both the *gem*-dimethyl group (0.3 p.p.m.) as well as the 4,6-methylenes (3.3 p.p.m.).

[7] G. C. Levy and G. L. Nelson, ' Carbon-13 Nuclear Magnetic Resonance for Organic Chemists,' Wiley–Interscience, New York, 1972, p. 24.

^{1}H *N.m.r. Spectra.* (*Table* 2).—Chemical shifts for two of these compounds (2a and g) have already been reported and the long-range shielding effects of the aryl substituents have been reationalized in these, as well as in the related spirotriketones (3), by De Jongh and Wynberg.[3] In dimedones carrying identical substituents at C-2, the *gem*-dimethyls as well as the C-4 and C-6 methylene protons are equivalent, due to conformational mobility, and show a single peak for each group. On the other hand, when the substituents are different, the two methyls at C-5 are not equivalent and the methylene hydrogens show an AB pattern.

In the asymetrically substituted dialkyl derivatives of dimedone, the lower chemical shift has been assigned to the methyl group *cis* to the larger substituent (R^2). Although this assignment is consistent with the calculated anisotropic effect of the aromatic ring [3] and possibly that of the double bond, the choice is arbitrary in the case of a β-cyanoethyl group.

EXPERIMENTAL

Proton noise-decoupled and single-frequency off-resonance decoupled (SFORD) natural abundance ^{13}C Fourier transform n.m.r. spectra of 1.0—2.0M solutions in deuteriochloroform, containing 10% (v/v) tetramethylsilane, were recorded on a Varian CFT-20 (20 MHz) spectrometer using standard parameters, with pulse angle of 30—37.5° (8—10 μs), aquisition time of 0.75—0.91 s, and without any pulse delay. The line positions and intensities were obtained relative to internal tetramethylsilane. Line positions (δ p.p.m.) are quoted to the nearest first decimal place. The ^{1}H n.m.r. spectra were recorded at 100 MHz on a Varian HA-100 spectrometer for 0.2—0.3M solutions in the above solvent–standard system. Melting points were determined on a Kofler block. Infrared spectra were recorded for KBr discs on a Perkin-Elmer 137 Infracord spectrophotometer.

The dimethyl (2a), diallyl (2c), and dibenzyl (2g) derivatives of dimedone were obtained as by-products in the corresponding monoalkylations, conducted according to the general procedure described by Stetter.[8] These three products have already been characterized by Desai.[9] The remaining dialkyldimedones were prepared by the following modifications of the described methods.[8]

Dialkyldimedones.[10]—To a solution of 2-alkyldimedone (10 mmol) in potassium t-butoxide–t-butyl alcohol (1N; 11 ml) was added alkyl halide (11 mmol) and potassium iodide (1 mmol). The mixture was gently refluxed on a water-bath for 14—20 h, when the reaction mixture was cooled and extracted with ether. The extracts were washed with 0.5N-sodium hydroxide and water and dried. Evaporation of solvent gave 80—100% yield of crude product, containing some *O*-alkylated compound (t.l.c., i.r.), which was refluxed (*ca.* 4 h) in aqueous ethanol (50%) containing 0.5—1.0% hydrochloric acid. After removing the excess ethanol on a rotary evaporator, the residue was dissolved in ether and washed with 0.5N-sodium hydroxide and water. Usual work-up afforded the dialkyldimedone, which was purified as described for individual compounds. Yields of the purified products were 60—75%.

2-*Allyl*-2-*methyldimedone* (2b), prepared as above from 2-allyldimedone and methyl iodide gave needles from petroleum ether (b.p. 40—60°), m.p. 41°; $\nu_{max.}$ 1 724, 1 695, and 1 639 cm^{-1} (Found: C, 74.0; H, 9.2. $C_{12}H_{18}O_2$ requires C, 74.2, H, 9.3%).

2-*Allyl*-2-*benzyldimedone* (2h), prepared as above from 2-benzyldimedone and allyl bromide gave rods from petroleum ether (b.p. 40—60°), m.p. 66—67°; $\nu_{max.}$ 1 724, 1 692, and 1 645 cm^{-1} (Found: C, 80.1; H, 8.3. $C_{18}H_{22}O_2$ requires C, 80.0; H, 8.2%).

2-*Benzyl*-2-*methyldimedone* (2f), prepared as above from 2-benzyldimedone and methyl iodide gave crystals from hexane, m.p. 49—50°; $\nu_{max.}$ 1 730 and 1 695 cm^{-1} (Found: C, 78.8; H, 8.4. $C_{16}H_{20}O_2$ requires C, 78.7; H, 8.3%).

2-(2-*Cyanoethyl*)-2-*methyldimedone* (2d). 2-Methyldimedone (1.85 g, 12 mmol), acrylonitrile (0.95 g, 18 mmol), and potassium t-butoxide (N; 1 ml) in t-butyl alcohol (15 ml) was gently refluxed for 15 h. The reaction mixture was cooled, diluted with benzene, and washed with water, 0.5N-sodium hydroxide, and water again. Drying, evaporation, and crystallization from 95% ethanol gave shiny plates (2.0 g, 82%); m.p. 100—101°; $\nu_{max.}$ 2 268, 1 730, and 1 698 cm^{-1} (Found: C, 69.7; H, 8.4; N, 6.9. $C_{12}H_{17}NO_2$ requires C, 69.5; H, 8.3; N, 6.8%).

2-*Allyl*-2-(2-*cyanoethyl*)*dimedone* (2j), prepared from 2-allyldimedone as for (2d) and crystallized from 95% ethanol gave rods (83%), m.p. 89—90°; $\nu_{max.}$ 2 278, 1 730, and 1 698 cm^{-1} (Found: C, 72.2; H, 8.4; N, 5.9. $C_{14}H_{19}NO_2$ requires C, 72.1; H, 8.2; N, 6.0%).

2-*Benzyl*-2-(2-*cyanoethyl*)*dimedone* (2i), prepared from 2-benzyldimedone as for (2d) and crystallized from 95% ethanol gave rods (64%), m.p. 130—135°, with softening at *ca.* 125°; $\nu_{max.}$ 2 257, 1 721, and 1 689 cm^{-1} (Found: C, 76.5; H, 7.4; N, 4.8. $C_{18}H_{21}NO_2$ requires C, 76.3; H, 7.5; N, 4.9%).

2,2-*Bis*-(2-*cyanoethyl*)*dimedone* (2e), prepared from dimedone as for (2d), with double the proportion of solvent, basic catalyst, and acrylonitrile, gave rods from 95% ethanol (40%), m.p. 139—140°; $\nu_{max.}$ 2 268, 1 727, and 1 692 (Found: C, 68.5; H, 7.2; N, 11.5. $C_{14}H_{18}N_2O_2$ requires C, 68.3; H, 7.4; N, 11.4%).

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[8] H. Stetter, in 'Newer Methods of Preparative Organic Chemistry,' ed. W. Foerst, Academic Press, New York, 1963, vol. 2, ch. 3.

[9] R. D. Desai, *J. Chem. Soc.*, 1932, 1079.

[10] J. R. Mahajan, *Synthesis*, 1976, 110.