

observed, due to the formation of tocopherylhydroquinone. Samples of this fraction were chromatographed on paper. After treatment with borohydride and development with 2,3,5-triphenyltetrazole in 0.2M phosphate buffer pH 7, one single spot was observed at the identical position of synthetic tocopherylquinone.

The fraction  $S_2$ , redissolved in a minimum amount (0.5 ml) of ethanol, gives a crop of yellow crystals at  $-20^\circ\text{C}$ . These were recrystallized from a smaller quantity (0.05 ml) of ethanol and were found to have a melting point at about  $4-5^\circ\text{C}$  and a spectrum in ethanol with bands at  $279\text{ m}\mu$  and  $405\text{ m}\mu$ . After reduction with borohydride the band in the visible region disappears and the peak in the UV is shifted to  $290\text{ m}\mu$  (Figure 2).

Paper chromatography of this fraction was run together with samples of pure Ubiquinone homologues. A spot was observed which has a  $R_f$  higher than Ubiquinone 30. CRAVEN's reaction for Ubiquinone was positive and gave the typical blue colour.

**Discussion and Conclusions.** The unsaponifiable fraction from the muscle tissue of *Spirographis spallanzani* contains a number of coloured substances which are not removed by treatment with Floridin, Decalso, Silicic acid

or Alumina. A good purification of the extract can be obtained by absorption on carbon. This treatment, however, is responsible for the oxidation of tocopherol to tocopheryl-quinone. Controls containing different amounts of synthetic tocopherol, as well as extracts to which tocopherol had been added, when treated with carbon, were found to contain only 25% of the original tocopherol, the remaining part of it having been transformed to tocopheryl-quinone.

After absorption on carbon of the extract, a second substance, closely resembling a Ubiquinone homologue, can easily be detected. This is liquid at room temperature and, in the oxidized state, shows a typical band in the UV with a peak at  $279\text{ m}\mu$ . All the Ubiquinone homologues have in ethanol an UV band displaced to shorter wavelength ( $275\text{ m}\mu$ ). The carbon treatment does not seem to be responsible for the shifting of the Ubiquinone band from  $275$  to  $279\text{ m}\mu$ . Ubiquinone 50 and 30, after absorption on carbon and elution with chloroform, show no change in their spectrophotometric properties. The low melting point could suggest a very short chain or perhaps a modified structure of the compound, whereas the peak at  $279\text{ m}\mu$  may indicate the presence of hydroxyl group(s) in the side chain<sup>15</sup>.

**Riassunto.** L'insaponificabile del muscolo di *Spirographis spallanzani* contiene accanto a steroli e tocoferolo, un composto di natura chinonica avente molte proprietà in comune con gli ubiquinoni. Anche il tocoferilchinone è stato identificato negli estratti. Si ritiene però che esso si formi dal tocoferolo durante il procedimento di estrazione.

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and F. GHIRETTI

Reperto di Fisiologia e Biochimica, Stazione  
Zoologica, Napoli (Italy), January 31, 1964.

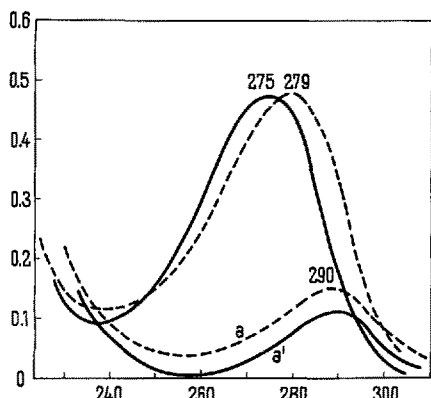


Fig. 2. Ultraviolet spectrum of fraction  $S_2$  (---) as compared with Ubiquinone 50 prepared from beef heart (—). a and a', after reduction with  $\text{KBH}_4$ .

<sup>15</sup> This work has been partially supported by a U.S. Public Health Service Grant (R.G. 4845). The authors gratefully acknowledge suggestions and criticisms from Dr. HEMMING and Dr. PENNOCK, Biochemistry Department, Liverpool.

## The Optical Rotatory Dispersion Curves of *trans*-Decalones and their Polycyclic Analogues<sup>1</sup>

Work on optical rotatory dispersion curves over the last 10 years has produced a mass of data on ketones, the  $n \rightarrow \pi^*$  carbonyl absorption band at  $290\text{ m}\mu$  being specially suitable for measurement. General reviews have been given<sup>2-4</sup>, and the ideas on this subject have been systematized in terms of the Octant Rule<sup>5</sup>. Extensive collections of data for six-membered ring ketones have been given elsewhere<sup>6,7</sup>.

It has been apparent for some time<sup>8</sup> that the amplitude ( $a$ ) of the Cotton effect is a convenient measure of the asymmetry of the surroundings of the carbonyl group. (The amplitude  $a$  is defined as the molecular rotation at the extremum of longer wavelength minus the molecular

rotation at the extremum of shorter wavelength; i.e. the difference between peak and trough, appropriately signed.) From the theoretical standpoint, the rotational

<sup>1</sup> Paper IX of the series *Optical Rotatory Dispersion*. For Paper VIII, see J. HRBEK JR., J. P. JENNINGS, W. KLYNE, and F. ŠANTAVÝ, Coll. Czech. Chem. Comm., 29, in press (1964).

<sup>2</sup> C. DJERASSI, *Optical Rotatory Dispersion; Applications in Organic Chemistry* (McGraw-Hill, New York 1960).

<sup>3</sup> W. KLYNE, in *Advances in Organic Chemistry* (Ed. R. A. RAPHAEL, Interscience, New York 1960), vol. 1.

<sup>4</sup> C. DJERASSI, *Pure appl. Chem.* 2, 475 (1961).

<sup>5</sup> W. MOFFITT, A. MOSCOWITZ, R. B. WOODWARD, W. KLYNE, and C. DJERASSI, *J. Am. chem. Soc.* 83, 4013 (1961).

<sup>6</sup> C. DJERASSI and W. KLYNE, *J. chem. Soc.* 1962, 4929.

<sup>7</sup> C. DJERASSI and W. KLYNE, *J. chem. Soc.* 1963, 2390.

<sup>8</sup> C. DJERASSI and W. KLYNE, *Proc. chem. Soc.* 1957, 55.

strength  $R_k$  is preferable<sup>9</sup>, but this involves elaborate calculations. In work on circular dichroism the molecular ellipticity ( $\theta$ ) serves the same purpose<sup>10,11</sup>.

*trans*-Decalin derivatives are especially valuable as reference compounds in this work, because their conformation is almost completely rigid (for reference to exceptions, see p. 352). Extensive series of compounds which may be considered as *trans*-1- or -2-decalones, with or without additional rings, and with or without angular methyl groups, have now been measured. These results can be tabulated to give an overall picture which is valuable for checking structures, configurations and conformations. The data are taken largely from the collections of Prof. C. DJERASSI (Stanford), and from our own work, together with some data from Prof. G. OURISSON's laboratory in Strasbourg. One vital reference compound (*trans*-2-decalone itself) has recently been provided, thanks to the kindness of Prof. V. PRELOG, E.T.H., Zürich<sup>12</sup>, and this enables us to offer the preliminary tables given herewith.

It is not suggested that the values given for the amplitudes are of high precision, but even as approximations they are useful for structural purposes. Comparison with circular dichroism data<sup>10,11</sup> in the future will be very valuable. The essential purpose of these tables is to examine the approximate magnitude of the amplitude contributions ( $\Delta a$ ) for angular methyl groups, and for the third and fourth rings fused on to a decalone system. For the purpose of standardizing symbols the ring carrying the carbonyl group is referred to as ring *A*, the adjacent ring as *B* and additional rings as *C* and *D*. (These letters are in many cases not the same as the letters allotted to the rings under the normal procedures of nomenclature for individual compounds.)

All compounds considered here have the standard *trans-anti-trans*-fusion of rings, and may be represented as variants of formulae I, III and IV. The Octant representations given are based on the pattern of the perfect

diamond lattice. In order to simplify comparisons some values given here are for the enantiomers of the compounds which have been measured. This is indicated by the prefix *E*. For present purposes, it is almost certainly immaterial whether the fourth ring *D* is five- or six-membered (see, for example, Table II, note j).

All values given here are for measurements in methanol at room temperature (18–25°). It is appreciated that further information may be gained at times from studies in different solvents (see, for example, RASSAT<sup>13</sup>, OURISSON<sup>14</sup>, DJERASSI<sup>15</sup>), and perhaps at different temperatures

Table II. R.D. amplitudes for *trans*-2-decalones. Values for *a* and  $\Delta a$  for additional rings

(i) General formula (III). Compounds related to 2-oxo-5 $\alpha$ -steroids.				
Substituents	$\begin{cases} X = \\ Y = \end{cases}$	$\begin{matrix} \text{H} & \text{H} & \text{Me} \\ \text{H} & \text{Me} & \text{H} \end{matrix}$		
<i>A</i> + <i>B</i> rings only		+54 <sup>a</sup>	+52 <sup>b</sup>	+71 <sup>c</sup>
With <i>C</i> ring		+71 <sup>d</sup>		
( $\Delta a$ )		(+17)		
With <i>C</i> + <i>D</i> rings				+101 <sup>e</sup>
( $\Delta a$ )				(+30)
(ii) General formula (IV). Compounds related to 3-oxo-5 $\alpha$ -steroids.				
Substituents	$\begin{cases} X = \\ Y = \end{cases}$	$\begin{matrix} \text{H} & \text{Me} & \text{H} & \text{Me} \\ \text{H} & \text{H} & \text{Me} & \text{Me} \end{matrix}$		
<i>A</i> + <i>B</i> rings only		+54 <sup>a</sup>	+52 <sup>b</sup>	+71 <sup>c</sup>
(as above)				
With <i>C</i> ring		+60 <sup>f</sup>	+53 <sup>g</sup>	
( $\Delta a$ )		(+6)	(+1)	
With <i>C</i> + <i>D</i> rings		+64 <sup>h</sup>	+54 <sup>i</sup>	+90 <sup>k</sup>
( $\Delta a$ )		(+10)	(+2)	(+19)

Table I. R.D. amplitudes of *trans*-1-decalones. Values for *a* and  $\Delta a$  for additional rings: General formula (I). (Letters <sup>a–f</sup> indicate the nature of the individual compounds studied, and references)

Substituents	$\begin{cases} X = \text{H} \\ Y = \text{H} \end{cases}$	$\begin{matrix} \text{H} \\ \text{Me} \end{matrix}$	$\begin{matrix} \text{Me} \\ \text{H} \end{matrix}$
<i>A</i> + <i>B</i> rings only	–40 <sup>a</sup>	+27 <sup>b</sup>	–60 <sup>c</sup>
With <i>C</i> ring	–58 <sup>d</sup>		
( $\Delta a$ )	(–18)		
With <i>C</i> + <i>D</i> rings		0 <sup>e</sup>	–94 <sup>f</sup>
( $\Delta a$ )		(–27)	(–34)

<sup>a</sup> C. DJERASSI and J. STAUNTON, J. Am. Chem. Soc. 83, 736 (1961) (*E*). – W. KLYNE and W. ROBERTSON, Exper. 18, 413 (1962).

<sup>b</sup> C. DJERASSI, R. RINIKER, and B. RINIKER, J. Am. Chem. Soc. 78, 6362 (1956).

<sup>c</sup> Calculated from values for hydroxy-derivatives kindly supplied by Prof. V. PRELOG. – W. KLYNE and W. ROBERTSON, Exper. 18, 413 (1962).

<sup>d</sup> 14-Oxo-des-D-steroid (as Köster-Logemann ketone), C. DJERASSI and W. KLYNE, Chem. & Ind. 1956, 988.

<sup>e</sup> 17 $\alpha$ -Oxo-D-homo-steroid. Plain curve, i.e. *a* = 0. (*E*) Ref. as <sup>b</sup> above.

<sup>f</sup> 4-Oxo-5 $\alpha$ -steroid (ring D of I is five-membered). – C. DJERASSI, W. CLOSSON, and A. E. LIPPMAN, J. Am. Chem. Soc. 78, 3163 (1956).

Notes and references. *E* indicates that the value in the Table is that for the enantiomer of the compound measured, i.e. the sign has been changed. Additional values for related compounds are given in <sup>6</sup> and <sup>7</sup>.

<sup>a</sup> Unsubstituted decalones; kindly provided by Prof. V. PRELOG and Dr. JAMBRESIC, E.T.H., Zürich.

<sup>b</sup> C. DJERASSI and J. E. GURST (Part 95), in press. See also <sup>6</sup> (*E*).

<sup>c</sup> C. DJERASSI and J. E. GURST (Part 95), in press.

<sup>d</sup> 12-Oxo-des-D-steroid; R. H. BIBLE JR. and R. R. BURTON, J. org. Chem. 26, 1174 (1961).

<sup>e</sup> 2-Oxo-5 $\alpha$ -steroid<sup>7</sup>.

<sup>f</sup> 13-Oxo-des-D-steroid<sup>7</sup>.

<sup>g</sup> 3-Oxo-des-D-steroid (A. C. AIREY, unpublished observation; prepared from material kindly supplied by Dr. G. ANNER, Ciba AG., Basel).

<sup>h</sup> 3-Oxo-19-nor-5 $\alpha$ -steroid (ring D of IV is five-membered)<sup>6</sup>.

<sup>i</sup> 3-Oxo-5 $\alpha$ -steroid<sup>7</sup> (ring D of IV is five-membered); also 3-oxo-D-homo-5 $\alpha$ -steroid (A. C. AIREY, unpublished observation) *a*, +54.

<sup>k</sup> 17-Oxo-D-homosteroid (*E*)<sup>7</sup>.

<sup>l</sup> 5-Methyl-3-Oxo-5 $\alpha$ -steroid (ring D of IV is five-membered)<sup>7</sup> – W. NAGATA, S. HIRAI, H. ITAZAKI, and K. TAKEDA, Liebig's Ann. 641, 184, 196 (1961).

Notes and references. (For meaning of *E*, see Table I)

<sup>9</sup> A. MOSCOWITZ, Chap. 12, in <sup>2</sup>.

<sup>10</sup> For a comparison of O.R.D. and C.D. as techniques in structural work, see C. DJERASSI, H. WOLF, and E. BUNNENBERG, J. Am. chem. Soc. 84, 4552 (1962).

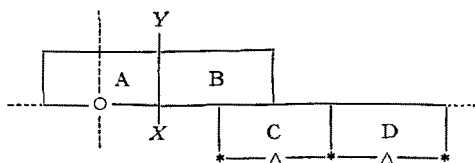
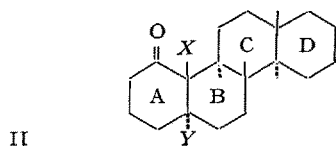
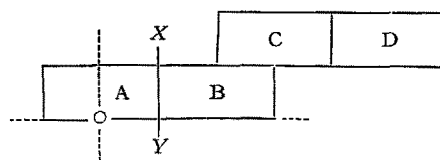
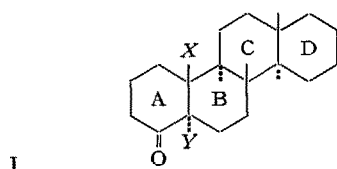
<sup>11</sup> P. CRABBE, Tetrahedron, in press (1964).

<sup>12</sup> V. PRELOG and I. JAMBRESIC, unpublished work.

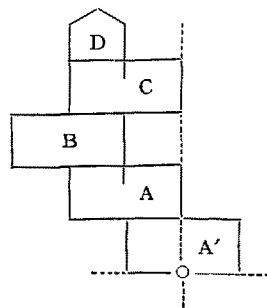
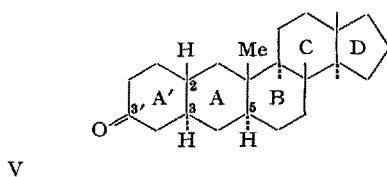
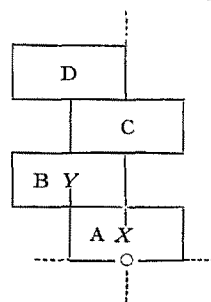
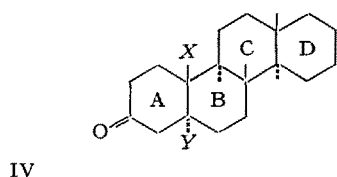
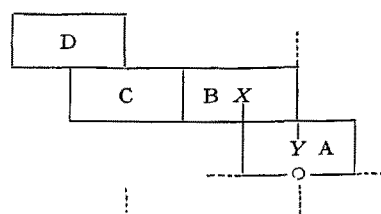
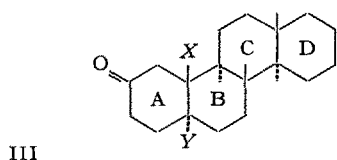
<sup>13</sup> H. P. GERVAIS and A. RASSAT, Bull. Soc. chim. Fr. 1961, 743.

<sup>14</sup> P. WITZ, H. HERRMANN, J.-M. LEHN, and G. OURISSON, Bull. Soc. chim. Fr. 1963, 1101.

<sup>15</sup> A. MOSCOWITZ, K. M. WELLMAN, and C. DJERASSI, Proc. Nat. Acad. Sci. Washington 50, 799 (1963).



\* Atoms in or near  $XY$  nodal plane.  $\Delta$  Atoms in front octant; negative contribution.



(see the important work of DJERASSI, MOSCOWITZ et al.<sup>16</sup> on temperature effects in circular dichroism measurements); however, for present purposes the above-mentioned standard conditions must suffice.

The *trans*-1-decalones considered here follow a single pattern, as (I); an alternative pattern (II), as found in 1-oxo-5 $\alpha$ -steroids, has some atoms in 'front octants'; these produce undesirable complications and this general type (II) is neglected here. Among the *trans*-2-decalones two groups represented by (III) and (IV) are both common; these may be looked upon as the analogues of 2- and 3-oxo-5 $\alpha$ -steroids, respectively.

The contributions of individual groups to amplitudes (or rotational strengths) have been dealt with in many other ways elsewhere - see, for example, the discussion by MOSCOWITZ<sup>17</sup> on the calculation of  $R_k$  values from struc-

tural formulae, and discussions by DJERASSI et al.<sup>18,19</sup> on the contributions of methyl groups at various positions in the cyclohexanone ring. Tables I and II, which summarize the data, show that it is possible to allot approximate  $\Delta a$  values to the angle methyl groups, and to additional rings C and D. These figures, rough as they are, are compatible

<sup>16</sup> K. M. WELLMAN, E. BUNNENBERG, and C. DJERASSI, J. Am. chem. Soc. **85**, 1870 (1963). - A. MOSCOWITZ, K. M. WELLMAN, and C. DJERASSI, J. Am. chem. Soc. **85**, 3515 (1963).

<sup>17</sup> A. MOSCOWITZ, Tetrahedron **13**, 48 (1961).

<sup>18</sup> C. DJERASSI, E. LUND, and A. A. AKHREM, J. Am. chem. Soc. **84**, 1249 (1962).

<sup>19</sup> C. BEARD, C. DJERASSI, J. SICHER, F. ŠIPOŠ, and M. TICHÝ, Tetrahedron **19**, 919 (1963).

with the idea that the amplitude contribution of a group falls off the farther the group is removed from the carbonyl chromophore<sup>5,17</sup>.

The contributions ( $\Delta a$ ) for the third and fourth rings (*C* and *D*) in general formulae I and III are in the range of 15–30 *a*-units. Contributions for the third and fourth rings in general formula IV, where ring *C* is almost symmetrical about the carbonyl group, are usually smaller.

Few compounds of perhydro-anthracene types are available for comparison, but one example may be mentioned from recent work in Strasbourg, viz. the A'-homosteroid ketone (V)<sup>20</sup>. The amplitude found (*a*, +95) suggests that the contribution of the third, fourth and fifth rings here is of the order of 40 units.

Tables I and II enable us to deduce values for methyl groups in various positions (some of which have already been discussed by DJERASSI et al.<sup>18,19</sup>); these are summarized in Table III.

It may be suggested that these Tables may be applied in structural work in the following way. One starts with the assumption that the  $\Delta a$  values of groups and additional rings fused on to a decalone are *additive*, and one works out the *expected a* value for a given structure, and compares it with the *observed* experimental *a* value. Discrepancies between expected and observed values may be treated as follows:

(a) Minor discrepancies (about 10 *a*-units) are presumably due to minor changes in conformation, and

should often be neglected – or their implications may be considered if a sufficient body of detailed data is available.

(b) Differences of medium size (20–30 *a*-units) are probably due to modified chair conformations, such as the flattened ring discussed recently by OURISSON<sup>21</sup> and by ALLINGER<sup>22</sup>.

(c) Major differences of the order of 50–100 *a*-units are sometimes to be ascribed to major conformational changes, such as the twist conformation (see DJERASSI and KLYNE<sup>23</sup>), or they may give rise to doubts regarding the structure or configuration of the compound concerned.

Similar tables can doubtless be prepared in due course for *cis*-fused decalone systems, for hexahydroindanonones, and for any other group of compounds in which many examples are available. In this kind of work, emphasis should be laid on the collection of data; important as are the reference values for certain key compounds, the nature of the semi-quantitative technique makes it necessary for the organic chemist to have figures for a *range* of compounds before drawing firm conclusions<sup>24</sup>.

*Zusammenfassung.* Der Einfluss von Methylsubstituenten, sowie von zusätzlich anellierten Ringen auf die Amplitude der Rotationsdispersionskurve von *trans*-Dekalon (1) und *trans*-Dekalon (2) wird durch Analyse eines umfangreichen Tatsachenmaterials ermittelt. Die in tabellarischer Form zusammengestellten, für den jeweiligen Substitutionstyp charakteristischen Beiträge verhalten sich in erster Näherung additiv und können deshalb zur Überprüfung von Strukturen, Konfigurationen und Konstellationen herangezogen werden.

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Department of Chemistry, Westfield College, Hampstead, London (England), March 23, 1964.

Table III. R.D. amplitude contributions of methyl groups attached to a cyclohexanone ring

Position of Me with respect to CO (cyclohexanone numbering)	Octant	$\Delta a$	Formulae Nos. (this paper)
2-axial	LR <sup>b</sup>	+67	I (b-a) <sup>c</sup>
3-axial	UR	–20	I (c-a)
	UR	–17	E III (c-a)
	UR	–26	E IV (k-h)
	UR	–19	E IV (l-j)
4-axial	a	–2	III (b-a)
	a	–10	IV (j-h)
	a	–17	IV (l-k)

<sup>a</sup> Ideally, these groups should be in the vertical symmetry plane and have zero  $\Delta a$  value; the actual value,  $\neq 0$  indicates, perhaps, some distortion.

<sup>b</sup> LR = lower right; UR = upper right.

<sup>c</sup> Letters a–k indicate footnotes in Tables I and II.

<sup>20</sup> J.-C. BLOCH, unpublished data. I am much indebted to Dr. BLOCH (Strasbourg) for permission to quote this value.

<sup>21</sup> J.-M. LEHN, J. LEVISALLES, and G. OURISSON, Bull. Soc. chim. Fr. 1963, 1096.

<sup>22</sup> N. L. ALLINGER and M. A. DAROOGHE, J. Am. chem. Soc. 84, 5461 (1962).

<sup>23</sup> C. DJERASSI and W. KLYNE, Proc. Nat. Acad. Sci. Washington 48, 1093 (1962).

<sup>24</sup> *Acknowledgment.* I am greatly indebted to Prof. V. PRELOG, E.T.H., Zürich, for important reference compounds and to Prof. C. DJERASSI, Stanford, and Prof. G. OURISSON, Strasbourg, for continuing exchange of information. I am grateful to the Department of Scientific and Industrial Research, the Wellcome Trust, and the U.S. Army Research and Development Group (Frankfurt am Main) for the financial support of this work.