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ROTATORY DISPERSION AND ITS APPLICATION IN ORGANIC CHEMISTRY

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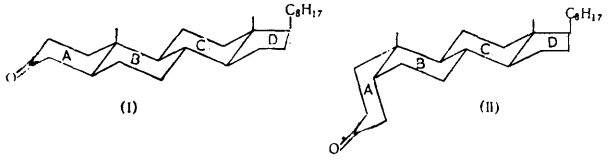
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I. INTRODUCTION

Recent years have seen the application of new physical methods in organic chemistry. Microwave spectroscopy, nuclear magnetic resonance, electron paramagnetic resonance, and other modern research methods have proved powerful tools in the hands of organic chemists. None of these methods, however, is very suitable for the study of problems connected with the spatial structure of molecules, especially questions of the relative and absolute configuration of organic compounds, which are of particular importance in the chemistry of natural products. Many stereochemical problems could be solved by X-ray, electron, and neutron diffraction methods, but unfortunately these procedures are frequently inapplicable because of the very nature of organic compounds. The most convenient method for the solution of problems of spatial structure would, of course, be the use of a physical phenomenon directly linked with the structure of the molecule and greatly dependent on the slightest changes in its configuration. Such a phenomenon has long been known to chemists. It is the variation in the optical activity of substances with change in the wavelength of the polarised light, *i.e.* the dispersion of the rotation of the plane of polarisation or the "rotatory dispersion".

Considering the conformations of molecules of cholestan-3-one (I) (*trans*-linking of rings A and B) and coprostan-3-one (II) (*cis*-linking of rings A and B), we can see that the environments of the keto-groups in the molecules are quite different.



It is quite evident that the rotatory dispersion (which is associated with the symmetry of the molecule) will also be completely different (see Section III). Consequently, even slight variations in the conformation of the molecule will greatly affect its symmetry, leading to a marked change in the rotatory dispersion curve, which thus becomes characteristic of the spatial arrangement of groups in the molecule. The practical value and the quite extraordinary sensitivity of rotatory dispersion as a method for studying the spatial structure of organic compounds were thoroughly investigated at the start of the present century in the work of Chugaev (for a detailed survey see Ref. 1) and several others (for review see Ref. 2). However, the lack of ultra-violet spectropolarimeters was a great obstacle. It is only during the past few years that suitable instruments have become available[3-6].

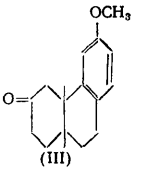
Since no reviews of this subject have been published in Russian, it appeared useful to examine some general aspects of the method of rotatory dispersion, and to cite individual examples to illustrate the possibilities of its application. Therefore the present review does not claim to be a complete account of the available facts, but is intended merely to direct attention to the main achievements of this new research method.

II. OPTICAL ROTATORY DISPERSION AND THE COTTON EFFECT

Refractive indices are known to increase markedly with decrease in wavelength. Furthermore, the refractive index of a substance measured in a region of the spectrum in which the latter has an absorption band exhibits a characteristic anomalous behaviour, as shown in Fig. 1.

Since the rotation of the plane of polarisation of light in an optically active substance is caused by the difference in refractive index between the right-hand and left-hand components of linearly polarised light, this phenomenon should obviously be governed by the same fundamental laws as the refractive index. Indeed, as early as 1821 Biot[7] had derived an empirical rule to represent the dependence of the specific rotation $[\alpha]$ on wavelength: $[\alpha] = A/\lambda^2$, where A is a constant characteristic of a given substance. It follows from this formula that, as with the refractive index, the specific rotation should increase on passing into the ultra-violet region of the spectrum.

The most striking example in support of this rule is provided by the behaviour of the tricyclic ketone (III) obtained from morphine[8]:



Over the range 700–500 mμ it was found to have no appreciable activity, whereas at 310 mμ its rotation reached +1172°.

The variation in rotation with the wavelength of the polarised light will also be analogous to that of the refractive index. An anomalous change in rotation occurs within

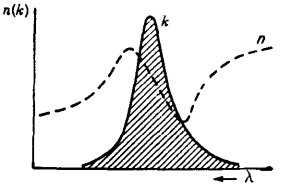


Fig. 1. Change in refractive index in the vicinity of an absorption band: n — refractive index; k — absorption coefficient.

an absorption band of an optically active substance. This was first discovered in 1896 by Cotton[9], and is known as the Cotton effect†. An absorption band in the spectrum of a substance is caused by energy losses due to excitation of a chromophoric group and the conjugated system as a whole. This is associated with the transition of electrons from one orbital to another, or from one state to another. This will, of course, change the nature of the interaction between the chromophore and the remainder of the molecule. And this change will primarily affect the symmetry (or dissymmetry) of the molecule, a direct consequence of which will be a marked distortion of the rotatory dispersion curve.

Thus the Cotton effect is in its very nature extremely sensitive to any variation in molecular structure, and it is for this reason that the rotatory dispersion curve is just as characteristic of a given substance as, for example, the characteristic infra-red vibrations of a functional group.

Fig. 2 shows typical curves for the variation of the absorption coefficient (log k) and molecular rotation $[M]$ with wavelength[10].

The Cotton effect can be either positive (+) or negative (-). A positive rotation on the long-wave side of an absorption band (Fig. 3A) indicates a positive Cotton effect, and a minus sign for the rotation on the long-wave side (Fig. 3B) implies a negative Cotton effect. In general, a change in the sign of rotation need not necessarily occur within an absorption band, but the anomalous character of the curve is still maintained.

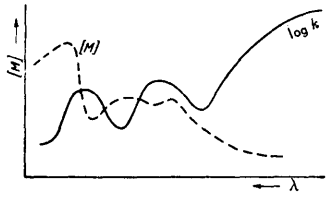


Fig. 2. Variation of absorption log k and molecular rotation $[M]$ with wavelength.

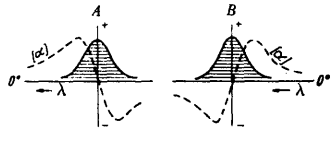


Fig. 3. Shape of curves for positive (A) and negative (B) Cotton effect.

† The concept of the "Cotton effect" includes also the problems of circular dichroism, but, although this is connected with the matter under discussion, it does not need to be dealt with here, since it is not required for the subsequent exposition.

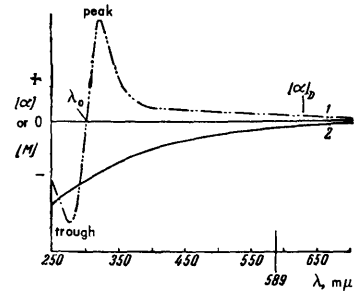


Fig. 4. 1) Anomalous curve (positive Cotton effect); 2) smooth curve.

Some substances do not exhibit the Cotton effect in the region of the spectrum accessible to measurement (usually the near ultra-violet), and a smooth dispersion curve (Fig. 4) is then obtained. This too can be utilised for the determination of molecular structure.

On the suggestion of Djerassi and Klyne[11], to avoid confusion, the maximum of the curve representing the Cotton effect is termed a "peak" (Gipfel, sommet, pik), and the minimum a "trough" (Tal, creux, trog). Such a terminology is appropriate, since the concepts of "maximum" and "minimum" already have a definite meaning in ultra-violet spectroscopy, and the terms "pik" and "trog" themselves have long been used in Russian (in geography and geology). The distance between them is called the "amplitude", and is characteristic of each type of molecular structure. If the curve shows additional peaks and troughs within an absorption band, it is said to be a complex Cotton-effect curve.

III. MAIN REGULARITIES OF ROTATORY DISPERSION AND THE "OCTANT RULE"

Since the Cotton effect is exhibited only within (or close to) an absorption band, its investigation requires that the substance should have a group which absorbs in the part of the spectrum selected. Such groups are termed, by analogy with dyes, chromophoric groups.

The chromophore is in most cases the carbonyl group, but other chromophoric groups can be used, containing, for example, sulphur (xanthates, dithiourethanes, thiones)[12-16], nitrogen (nitroalkanes, nitriles, azides, etc.)[17-21], halogens[22-25], aromatic rings[17,18,26,27], and also such uncommon groups as diselenide[28] and dipyrrolylmethyl[29]. Rotatory dispersion has been most thoroughly studied in the near ultra-violet (down to ~230–250 mμ), because organic chemists deal largely with colourless substances having absorption bands in the ultra-violet. Furthermore, it is possible in this region to work with very small amounts of material (of the order 0.1–1 mg), since, as already mentioned, the rotation increases markedly on passing into the ultra-violet region of the spectrum.

Although 150 years have elapsed since the discovery of the phenomenon of optical activity by Arago (1811), and a comprehensive study has been made of the phenomenon, especially with the aim of finding a relation between the

structure of optically active substances and the nature of the rotation, no rigorous or sufficiently general theory has yet emerged. On the basis of a huge amount of experimental data, it has been possible to establish only a multitude of empirical rules, which, although having no theoretical foundation, have proved useful for elucidating and systematising most of the observed facts. These rules have been carefully tested by Djerassi and his coworkers on more than 2000 optically active substances[28,30,31]. Some of the most general of these empirical rules are given below.

1. Kuhn[32] discovered experimentally and explained theoretically a rule forming the basis of the method, according to which weak absorption bands produce a marked change in rotation, *i.e.* a strong Cotton effect. It is for this reason that aldehydes and ketones have been investigated for the most part, as they have a characteristic band of very low extinction in the ultra-violet (λ_{max} 280–300 mμ, ϵ_{max} ~50).

2. Chugaev's proximity rule[33-36]: (*a*) substances of similar structure undergo identical changes in rotation with changes in structure; (*b*) an identical change in structure produces a smaller change in rotation, the farther it is from the chromophoric group and from the asymmetric atom.

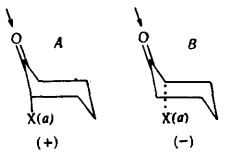
These two rules are the most general.

3. Change in the mode of linking of the rings (*cis* or *trans*) in steroid ketones and their bicyclic analogues involves a change in the sign of the Cotton effect (see Fig. 5). The presence of various other substituents (hydroxyl, ether group, lactone, acyl, etc.) or even of a double bond can be ignored, provided that they do not affect the conformation of the molecule. The only exceptions are other ketone or aldehyde groups[37].

4. Angular substituents do not appreciably affect the shape of the curve representing the Cotton effect[38,39].

5. The axial "halogeno-ketone rule" enables us to determine the sign of the Cotton effect in halogenated cyclic ketones[40,41]: introduction of a halogen atom (other than fluorine) into the axial position α to the keto-group reverses the sign of the Cotton effect and greatly increases the amplitude.

The sign of the Cotton effect can be determined by looking at the molecule from the point of view of the keto-group:



With cyclohexane in the "chair" form, for example, the Cotton effect will be positive if the axial halogen atom is located to the right of the observer (*A*), and negative if the halogen atom is to the left (*B*). The rule is applicable also to polycyclic systems. Equatorial halogen atoms do not influence the sign of the Cotton effect[42].

6. The sign of the Cotton effect changes on passing from five- to six-membered rings, and from six- to seven-membered rings.

7. "The 4,4-dimethyl effect"[37]. Introduction of two methyl groups into the 4-position of 3-keto-steroid and related systems causes a reversal in the sign of the Cotton effect. Introduction of only one methyl group produces no change at all. This phenomenon is not caused by 1,3-diaxial interaction between axial methyl groups attached to C_4 and C_{10}.

8. "The octant rule"[31]. Consideration of a vast quantity of experimental results has enabled a quite simple rule — the so-called "octant rule" — to be derived, enabling us to predict the nature of the curve representing the Cotton effect from the spatial structure of the molecule. Since all the remaining rules are merely particular cases deriving from this rule, and since, moreover, the determination of absolute configuration is based on it, we must consider it in greater detail (see Fig. 6).

If the cyclohexanone molecule is intersected by three mutually perpendicular planes, in such a way that plane *A* passes through the O, C_1, and C_4 atoms, plane *B* through C_1, C_2, and C_6, and plane *C* between the O and C_1 atoms,

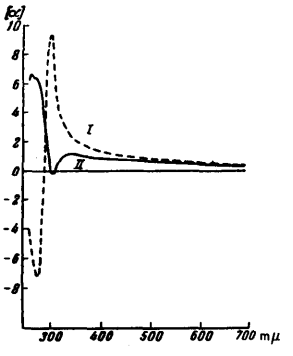


Fig. 5. Rotatory dispersion of: I) cholestan-3-one; II) coprostan-3-one.

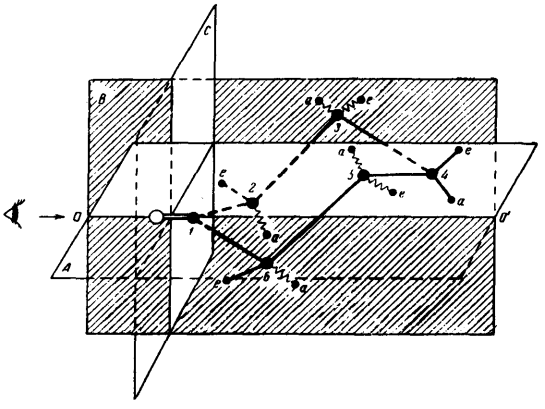


Fig. 6. Diagram illustrating the "octant rule".

the whole molecule will be divided into eight parts or octants. It is then seen that the C_3 and C_5 atoms lie outside the planes, equatorial (*e*) substituents attached to C_2 and C_6 lie in plane *B*, and both equatorial (*e*) and axial (*a*) substituents attached to C_4 lie in plane *A*.

The octant rule states: (1) To a first approximation, no substituent lying in one of the planes has any effect on the form of the curve representing the Cotton effect. (2) All carbon atoms and other groups located in the octants *II* (far upper left, looking at the molecule along the axis *OO'*), *IV* (near lower left), *V* (near upper right), and *VII* (far lower right) change the rotation to more positive values (make a positive contribution to the Cotton effect). With cyclohexanone, this type of change will be produced by axial and equatorial substituents attached to C_3 and by axial substituents attached to C_6. (3) Carbon atoms and other substituents situated in the remaining octants (*I*, *III*, *VI*, and *VIII*) change the rotation to more negative values (make a negative contribution to the Cotton effect). Such an effect will be exerted in cyclohexanone by axial and equatorial substituents attached to C_5 and by axial substituents attached to C_2. (4) The magnitude of the positive or negative contribution to the Cotton effect depends in general on the size of the substituents, since it determines the extent to which the symmetry of the molecule is destroyed. Thus 3-methyl--5-t-butylcyclohexanone, for example, should exhibit a negative Cotton effect, while interchange of the substituents should make it positive, since the t-butyl group is larger than the methyl group.

Fig. 6 can be represented schematically by a so-called "octant diagram" (Fig. 7) if we look at the molecule along

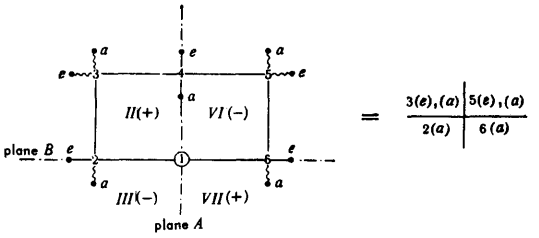


Fig. 7. Simplified diagram of octant rule.

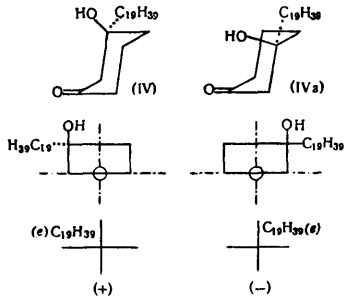


Fig. 8. Determination of the configuration of 3-hydroxy-3-nonadecylcyclohexanone.

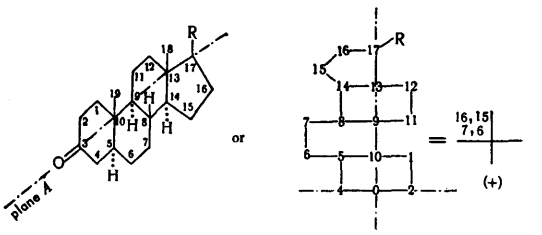


Fig. 9. Octant diagram for 3-oxo-5α-steroids.

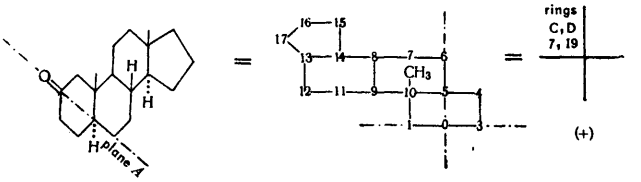


Fig. 10. Octant diagram for 2-oxo-5α-steroids.

TABLE. [31] Cotton effect in 5α-steroid ketones.

Position of oxo-groups	Arrangement of substituents (octant diagram)		Cotton effect	
			predicted	found
2	7, 19, rings C and D		+++	+121
3	16,15,7,6		+	+ 65
4		19, rings C and D	— —	— 94
6	19	12, 18, ring D	— —	— 76
7	16,15	2,3	—	— 16
11	16,18	6 **2**	+	+ 16
12	2,3,4,5,6	18, side-chain	++	+ 42

Note. The bold type denotes atoms located in the near octants (I, IV, V, and VIII).

the axis *OO'* and ignore the near octants (the Roman numerals in Fig. 7 denote the numbers of the octants).

We shall discuss a few cases of the application of this rule.

1. In the 3-hydroxy-3-nonadecylcyclohexanone molecule (IV) the nonadecyl group is considerably larger than the hydroxyl group, so that, according to the conformational rules, it should occupy the equatorial position. Hence the absolute configuration (IV) can be readily established from an examination of the Cotton effect curves (Fig. 8).

If the compound does have configuration (IV), its Cotton effect should be positive (both substituents situated in

octant *II*). If, however, the absolute configuration of this molecule is represented by (IVa), the Cotton effect will be negative (both substituents located in octant *VI*). It has been shown experimentally[28] that 3-hydroxy-3-nonadecylcyclohexanone has a positive Cotton effect, and hence its absolute configuration corresponds to formula (IV).

2. Similar reasoning can be applied to more complex molecules. If 5α-steroids (with *trans*-linking of rings A and B) are examined on the basis of the octant rule, the diagram obtained for 3-oxo-5α-steroids shows that they should possess a positive Cotton effect (see Fig. 9).

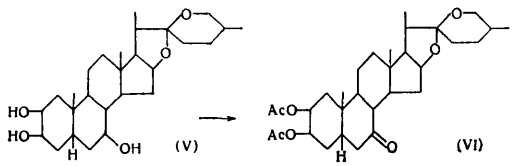
Fig. 10 shows the octant diagram for 2-oxo-5α-steroids, according to which they too should possess a positive Cotton effect, as is actually observed. A detailed study of the Cotton effect in other 5α-steroids also confirmed the correctness of the octant rule. Several of the results obtained are given in the Table.

IV. SOME APPLICATIONS OF ROTATORY DISPERSION

It is clear from the above account that the new method of investigation can be employed in all cases entailing determination of the spatial structure of molecules, which is a most important problem of modern organic chemistry. Among a large amount of experimental work involving the application of rotatory dispersion, only those cases will be considered below which illustrate particularly clearly the inherent potentialities of this new method.

1. Orientation of a Hydroxyl Group in Trihydroxymetagenin (V)[43]

The structure of this sapogenin has been almost completely established by chemical methods, apart from the position of one hydroxyl group. In order to solve this problem, the triol (V) was oxidised to the keto-diol derivative (VI), and the rotatory dispersion curve of the latter was determined.

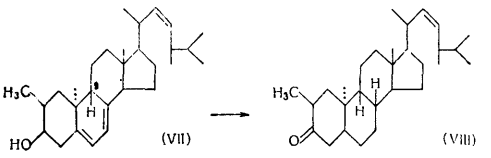


The curve was found to differ from all known curves for the Cotton effect obtained with oxosapogenins[44], but corresponded fully to the curve characteristic of 7-oxosteroids with *cis*-linkage of the A and B rings. Hence this hydroxyl group in trihydroxymetagenin (V) is attached to C_7, which was subsequently confirmed by chemical means.

2. Use of Rotatory Dispersion in Solving Stereochemical Problems

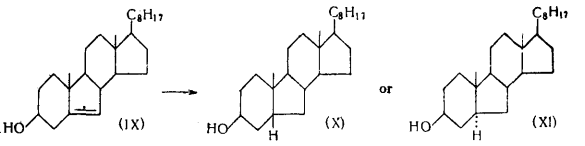
Determination of absolute configuration and its relation to optical rotation forms one of the most important tasks of theoretical chemistry. However, its solution has encountered immense difficulties. It was only in 1958 that the relation between the left-hand rotation of α-quartz and its structure (right-hand spiral in the crystal lattice) was finally established with certainty[45]. Several examples have shown that measurement of the rotatory dispersion often enables such problems to be solved quite reliably.

(*a*) Stereochemistry of the C_9 atom in lumisterol (VII).[46,47] In order to establish the stereochemistry of the C_9 atom, lumisterol (VII) was converted to the cyclic ketone (VIII):



The curve for the Cotton effect in this ketone is the mirror image of that for coprostan-3-one (II) (see Fig. 1), which corresponds to the 8β,9β-configuration in (VIII), and hence the 9β-configuration in lumisterol itself (VII). This conclusion was subsequently confirmed by chemical methods.

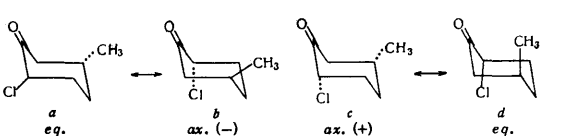
(*b*) Stereochemistry of the link between six- and five-membered rings in B-norcholestanol (X)[48] [This section has been modified to accord with the sources quoted (Ed. of Translation)]. B-Norcholestanol, formed by the hydrogenation of (IX), can posses one of the two possible configurations (X) or (XI) with *cis*- or *trans*-linkage of the A and B rings:



In order to solve this problem, the hydrogenated product was oxidised to the ketone, whose rotatory dispersion curve is given in Fig. 11. This shows that the ketone has a *cis*-linkage of the A and B rings, and hence that B-norcholestanol itself has the same configuration (X), although all the early chemical and spectroscopic data had indicated[49] the presence of a *trans*-linkage.

A later, more rigorous investigation[50] confirmed Djerassi's results. The reason for the error was that the earlier workers had applied to B-norsteroids chemical and spectroscopic rules obtained with steroids having a six-membered B ring.

(*c*) Determination of the configuration of 2-chloro-5-methylcyclohexanone. This compound (XII) can exist in four different chair conformations:



(XII)

It had previously been found[51] that conformations having the chlorine atom in the axial position (*i.e.* *b* or *c*) predominate

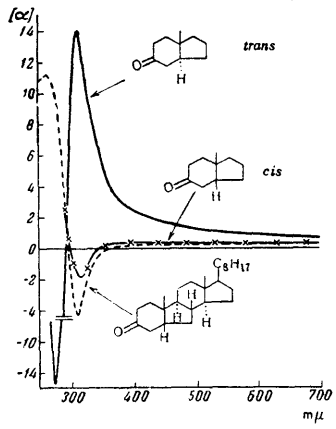


Fig.11. Confirmation of the configuration of B-norcholesterol.

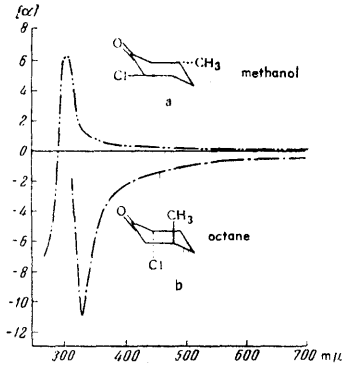


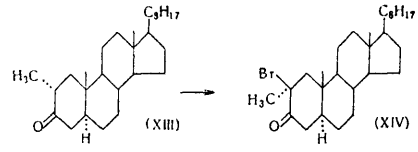
Fig.12. Change in the conformation of 2-chloro-5-methylcyclohexanone.

in non-polar solvents (for example, in octane), whereas the equatorial forms (*a* or *d*) predominate in polar solvents (for example, in methanol). However, it was impossible by means of spectroscopy to decide to which series (*cis* or *trans*) these conformations belong.

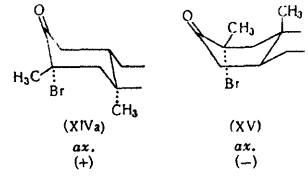
It is readily seen from the "halogeno-ketone rule" (Section III) that, of the two forms with the chlorine atom in the axial position, only one (*b*) will possess a negative Cotton effect, whereas the other (*c*) should show a positive effect. Hence if a negative Cotton effect is observed in octane, and a positive effect in methanol, 2-chloro-5-methylcyclohexanone (XII) will belong to the *trans*-series, whereas if the Cotton effect has the opposite signs, the compound will have the *cis*-configuration. An experimental check (Fig.12) showed that the change in the form of the curves corresponds to the first case, and hence that 2-chloro-5-methylcyclohexanone has the *trans*-configuration[52].

The change in sign of the Cotton effect with the polarity of the solvent provides a confirmation of the conformational mobility of cyclohexane systems.

(*d*) Proof of the boat form of the A ring in 2α-methylcholestan-3-one. On the basis of the ultra-violet and infra-red spectra, it had been accepted[53] that the product formed by bromination of 2α-methylcholestan-3-one (XIII) has the structure 2β-bromo-2α-methylcholestan-3-one (XIV):



Since it has been proved that the bromine occupies an axial position in this molecule, its configuration could be confirmed by the "halogeno-ketone rule" (Section III), according to which XIV should have a positive Cotton effect (bromine atom on the right):

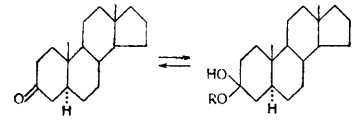


The compound was found, however, to exhibit a negative Cotton effect. As can be seen from the conformational formulae, this is possible only if the A ring has the boat form (XV). This result shows that the A ring in steroids exists in some cases in the boat form and not in the chair form, as had been assumed.

3. Rotatory Dispersion Study of the Formation of Ketone Acetals and Hemiacetals

It has been shown earlier[54] that, when an acid is added to an alcoholic solution of a ketone, an equilibrium is established between the ketone and a hemiacetal (or an acetal). Since this involves the disappearance of the chromophoric group, and thereby the conversion of the anomalous curve representing the Cotton effect to a smooth curve, this phenomenon can be utilised for the study of structural and steric problems. The following empirical rules have been established[55] with polycyclic ketones as examples.

(*a*) The changes in amplitude and shape of the curve representing the Cotton effect are very sensitive to steric factors. Replacement of methanol by ethanol, for example, produces a marked shift in the equilibrium towards hemiacetal formation, while replacement of methanol by propan-2-ol completely suppresses the formation of a hemiacetal:

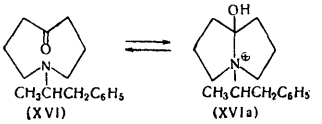


(*b*) Hemiacetals are formed more readily by six-membered ring ketones than by those with a five-membered ring.

(*c*) The presence of substituents in the vicinity of the keto-group impedes this process.

(*d*) If the resulting acetal can undergo 1,3-diaxial interaction with an angular methyl group, acetalisation does not take place. This provides a ready means for distinguishing 2- and 3-oxo-5α-steroids, since the former do not yield hemiacetals, and hence the form of the Cotton effect curve is not changed on addition of acid to their alcoholic solutions.

Study of the rotatory dispersion curves during acetal formation has provided solutions to several difficult problems associated with the structure of a number of organic compounds. Thus the possibility of transannular interaction within the eight-membered cyclic ketone (XVI) has been demonstrated by means of this method. It has been established[56] that, on addition of acid to this ketone, its characteristic negative Cotton effect curve is converted to a smooth positive dispersion curve. This means that the chromophoric group has disappeared, which can be readily explained by interaction of the keto-group with the nitrogen atom (XVIa):



This method has been used to determine the position of the hydroxyl group in two macrolides (methymycin and neomethymycin). The problem was solved[57,58] with their dehydro-derivatives (XVII) and (XVIII). Dehydromethynolide (XVII) was found on addition of acid to give only a smooth dispersion curve (Fig. 13) instead of the characteristic Cotton effect curve, which indicates its ability to form a cyclic hemiacetal. The Cotton effect curve of the second product — dehydroneomethynolide (XVIII) — undergoes no change under these conditions, and hence the hydroxyl group in (XVIII) must be so situated that intramolecular hemiacetal formation cannot take place.

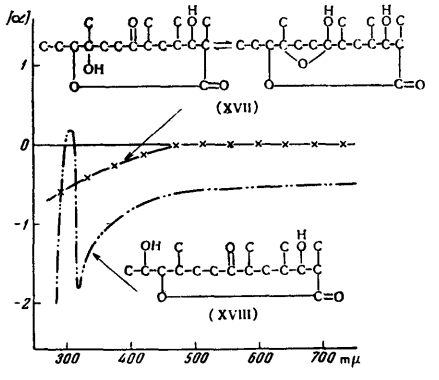


Fig. 13. Demonstration of the position of the hydroxyl group in methymycin and neomethymycin.

4. Employment of Smooth Rotatory Dispersion Curves in Some Structural and Stereochemical Problems

A smooth dispersion curve does not, of course, enable us to settle fine points of structural chemistry, and therefore the opportunities for its employment are for the present limited. Nevertheless, it is more useful for structure determination than the usual measurement of optical activity in the visible region (~500–700 mμ). It must also be remembered that a smooth rotatory dispersion curve may become anomalous in another region of the spectrum.

(*a*) Difference in the curves for cholestene isomers[59]. All cholestene (XIX) isomers have a smooth dispersion curve in the measurable region. Fig. 14 shows, however, that the curve for each isomer differs from those for the others, and this can be used for the identification both of the isomers themselves and of compounds of analogous structure, such as the pentacyclic terpenes.

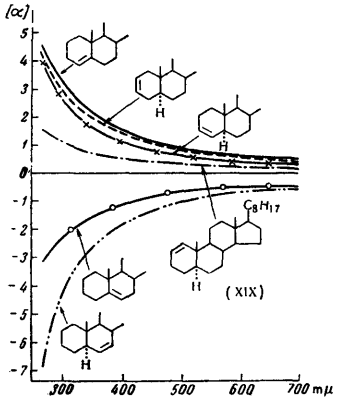


Fig. 14. Rotatory dispersion of cholestene isomers.

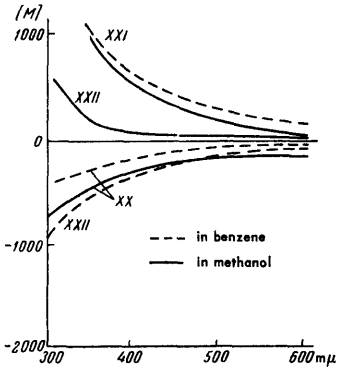
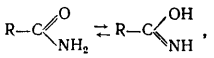
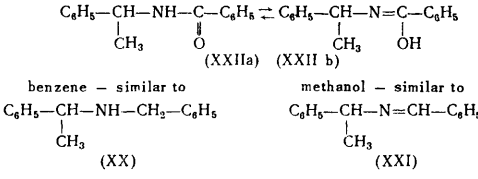


Fig. 15. Use of rotatory dispersion to prove the occurrence of tautomerism in amides.

(*b*) Study of tautomerism [60,61]. In order to demonstrate the tautomerism of amides



a study was made of the rotatory dispersion curves of α-methyldibenzylamine (XX), *N*-benzylidene-α-methylbenzylamine (XXI), and *N*-(α-methylbenzyl)benzamide (XXII) in methanol and in benzene (Fig.15). It was found that the curves for (XX) and (XXI) changed little on passing from benzene to methanolic solutions, but with (XXII) the curve in benzene was similar to that for (XX), while the curve in methanol resembled that for (XXI).



The conclusion was drawn that *N*-(α-methylbenzene)benzamide (XXII) occurs in the amide form (XXIIa) in benzene, and in the imide form (XXIIb) in methanol. This was subsequently confirmed by a study of the crystalline forms of XXII.

The smooth rotatory dispersion curve is widely employed also for investigating the structure of proteins, polypeptides, and other substances of high molecular weight (see, for example, Ref.62), but these questions are beyond the scope of the present paper.

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It is evident even from the few examples discussed above that study of rotatory dispersion and the Cotton effect open up very great possibilities in the stereochemistry of complicated molecules. At the present time, when this method is still only in its initial stages, it is difficult to predict its future development. It is quite clear, however, that it will soon become just as irreplaceable a tool in the hands of the organic chemist as infra-red and ultra-violet spectroscopy have become.

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PROGRESS IN THE ANALYSIS OF INORGANIC AND ORGANIC COMPOUNDS IN NON-AQUEOUS SOLUTIONS

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N.A.Kazaryan, and N.Sh.Aldarova

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I. INTRODUCTION

Until recently, chemists used chiefly chemical and physicochemical methods of analysis in the study of matter, based on reactions in aqueous solutions. As a result, while physical chemists up to the end of the 19th century studied the properties of aqueous solutions, analytical chemists developed methods of analysis in such solutions. At the present time all the theories, definitions and chemical and physicochemical methods of analysis in analytical chemistry are based on principles developed for aqueous solutions.

The rapid increase in the production of monomeric and polymeric organic compounds led to considerable interest in the analytical chemistry of non-aqueous solutions since analytical methods developed for aqueous solutions are inapplicable to such compounds. This is indicated by the ever-increasing number of original and review articles and monographs published in different countries on problems associated with the theory of non-aqueous solutions and their practical application[1-26].

The idea of using non-aqueous solutions for analytical purposes has recently attracted the attention not only of analytical chemists, but also of many physical and organic chemists[27-53].

In non-aqueous solutions it is possible to determine various compounds by alkalimetric and acidimetric titration[54-80]. On the basis of the specific properties shown by salts in non-aqueous solutions, it is possible to titrate non-aqueous salt solutions successfully by the precipitation method, making use of the insolubility, in non-aqueous solvents, of certain salts which are soluble in water[81-83]. Since the solvents influence redox potentials, it is possible to titrate non-aqueous solutions by oxidimetric methods[84-96]. The use of non-aqueous solutions for analytical purposes can also be extended to complexometric, photometric, chromatographic, electrochemical, and other analytical methods[97-114].

In view of the vast amount of published work on all these methods, we shall in the present review consider only acid-base titration methods in non-aqueous solutions, of greatest theoretical and practical interest.

The use of non-aqueous solvents makes it possible to extend considerably the possibilities of acid-base titration. Methods of non-aqueous titration are of great importance in the study of inorganic substances and particularly for the analysis of monomeric and polymeric organic compounds. The application of non-aqueous solutions in analysis is extremely promising, since it shows a number of advantages over aqueous solutions[15,17].

Considerable progress has now been made in the analysis of inorganic and organic compounds, and of organic derivatives of the elements, in non-aqueous solutions. It is sufficient to point out that only by acid–base titration in non-aqueous media is it possible to determine compounds irrespective of their pK, isomers, chemical compounds of the same homologous series, substances which have nothing in common with our usual ideas of acids and bases, multicomponent mixtures of various compounds, etc. This progress is due chiefly to the development of the chemical theory of solutions, whose foundations were laid by the Russian school of D.I.Mendeleev[17,20,26,115-130].