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(54) **METHOD OF DETERMINING ABSOLUTE CONFIGURATION OF CHIRAL COMPOUND**

VERFAHREN ZUR BESTIMMUNG DER ABSOLUTEN KONFIGURATION VON CHIRALEN
VERBINDUNGEN

DETERMINATION DE LA CONFIGURATION ABSOLUE D'UN COMPOSE CHIRAL

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DescriptionTECHNICAL FIELD

5 **[0001]** The present invention relates to a method for determining the absolute configuration of chiral compounds.

BACKGROUND ART

10 **[0002]** Conventionally, there have been attempts to determine the absolute configuration of external ligands based on the induced Cotton effects revealed by the analysis of circular dichroism (CD) spectrophotometry. For example, the following are reported:

(1) E. Yashima, T. Matsushima, and Y. Okamoto (J. Am. Chem. Soc., 1997, 119, 6345-6359) report on polymers forming a helical structure in the presence of a chiral compound and describe that there is a good correlation between the sign of the Cotton effect in the circular dichroism spectra induced by the ligand (chiral compound) and the absolute configuration of the ligand.

However, since the helical structure is induced by the ion pair formed between the carboxylate group of the polymer side chain and the ammonium group of the ligand, this method can be used for typical monoamines and aminoalcohols but is not applicable to alcohols.

(2) X. Huang, B. H. Rickmann, B. Borhan, N. Berova, and K. Nakanishi (J. Am. Chem. Soc., 1998, 120, 6185-6186) report on circular dichroism induced in a long chain-crosslinked porphyrin dimer by a chiral ligand. There is a correlation between the sign of the Cotton effect and the absolute configuration of the ligand. In this system, however, circular dichroism is induced only when one ligand molecule is concurrently coordinated to two porphyrin units. Therefore, this method is useful only for bifunctional compounds such as diamines and aminoalcohols.

(3) M. Takeuchi, T. Imada, and S. Shinkai (Bull. Chem. Soc., Jpn., 1998, 71, 1117-1123) report that a porphyrin dimer having a phenylboronic acid unit exhibits circular dichroism in the presence of a variety of sugars.

This method is applicable only to polyols (polyalcohols) which form a chemical bond with boronic acid, and it is not a method for directly determining the absolute configuration around a specific asymmetric center.

(4) H. Tsukube, M. Hosokubo, M. Wada, S. Shinoda, and H. Tamiaki (J. Chem. Soc., Dalton Trans., 1999, 11-12) report that a tris(β -diketonato) lanthanide complex exhibits circular dichroism in the presence of chiral amino alcohols. In this system, however, monoamines or monoalcohols do not induce chirality.

(5) S. Zahn, and J. W. Canary (Org. Lett., 1999, 1, 861-864) report that the absolute configuration of amino acids and aminoalcohols can be determined based on the circular dichroism of their copper complexes.

However, this method is applicable only to bidentate amino acids and aminoalcohols and can not be used for monoamines or monoalcohols.

Other methods employing metalloporphyrin dimers have been disclosed by Rickman et al., Tetrahedron 54 (1998)5051-5064; Hayashi et al., Tetrahedron Letters, Vol. 38, No. 9 (1997)1603-1606; and Liu et al., Chem. Comm. (1997) 1575-1576. Metalloporphyrins are described in Borovkov et al., Helvetica Chimica Acta, Vol., 82 (1999) 919-934; and Borovkov et al., Synlett, No. 7 (1998) 768-770.

As is clear from the above, there have been no reports about a method for determining the absolute configuration of chiral compounds having a wide variety of basic groups, such as monoalcohols.

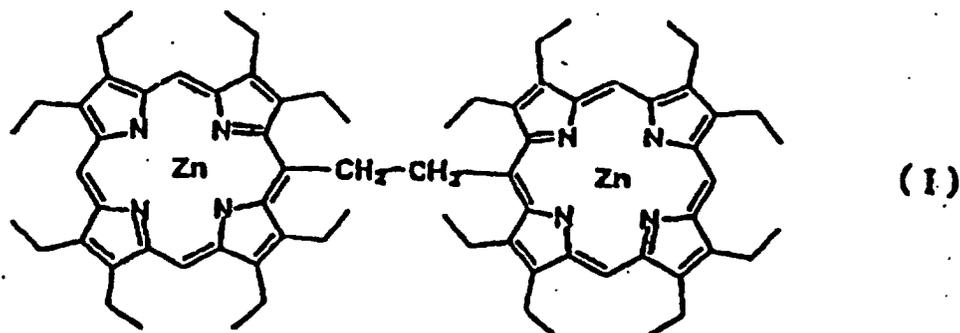
The X-ray diffraction method is known as a method for determining the absolute configuration of chiral compounds. However, there is a limitation in that this method is applicable only to crystalline compounds.

DISCLOSURE OF THE INVENTION

[0003] The principal object of the present invention is to overcome the limits and problems of the prior art and to provide a general-purpose method for precisely and easily determining the absolute configuration of chiral compounds having a wide variety of basic groups.

[0004] The present invention provides a method for determining the absolute configuration of a chiral compound which comprises:

coordinating the chiral compound to a metalloporphyrin represented by the following formula (I):



15 $\{\mu\{[5,5'-(\text{ethane-1,2-diyl})\text{bis}[2,3,7,8,12,13,17,18\text{-octaethyl-21H,23H-porphyrinato}(4-)] - \kappa\text{N}^{21}, \kappa\text{N}^{22}, \kappa\text{N}^{23}, \kappa\text{N}^{24}, \kappa\text{N}^{21'}, \kappa\text{N}^{22'}, \kappa\text{N}^{23'}, \kappa\text{N}^{24'}\}\text{dizinc};$

the chiral compound having an asymmetric carbon bonded to a basic group capable of coordinating to the metal of the porphyrin ring of the metalloporphyrin or an asymmetric carbon atom adjacent to the carbon atom bonded to the basic group; and

20 analysing the resultant coordination compound by circular dichroism spectrophotometry to determine the absolute configuration of the asymmetric carbon of the chiral compound based on the sign of the Cotton effect.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005]

Fig. 1 shows the circular dichroism of a zinc porphyrin dimer induced by a chiral amine.

Fig. 2 is a schematic diagram showing the mechanism of asymmetric induction in a zinc porphyrin dimer.

Fig. 3 illustrates the moment directions of the maximum absorption band of a porphyrin dimer.

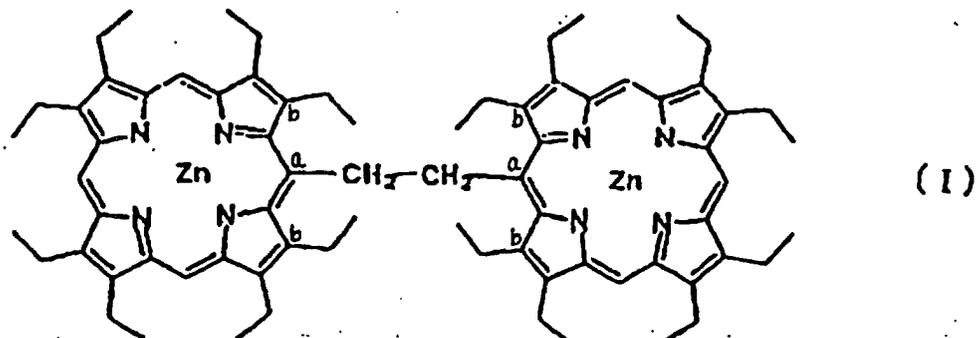
Fig. 4 shows CD spectra obtained using (R)-(-)-1-cyclohexylethylamine in the Example.

Fig. 5 shows CD spectra obtained using (R)-(-)-phenylethanol in the Example.

[0006] The present invention uses circular dichroism (CD) spectrophotometric analysis as described above. In this analysis, the sign of the induced Cotton effect is determined by the absolute configuration of the asymmetric carbon of the external ligand. According to the CD exciton-chirality method (Harada, N.; Nakanishi, K.; Circular Dichroic Spectroscopy-Exciton Coupling in Organic Stereochemistry; University Science Books; Mill Valley, 1983.; Nakanishi, K.; Berova, N. In Circular Dichroism; Principles and Applications; Woody, R., Ed; VCH Publishers; New York, 1994; pp. 361-398), a clockwise orientation of two interacting electronic transition moments produces positive chirality, while a counterclockwise orientation leads to negative chirality.

[0007] The present invention was accomplished based on the finding that there is a specific correlation between the sign of the Cotton effect and the absolute configuration of the asymmetric carbon of a chiral compound (R-isomer or S-isomer) as a ligand.

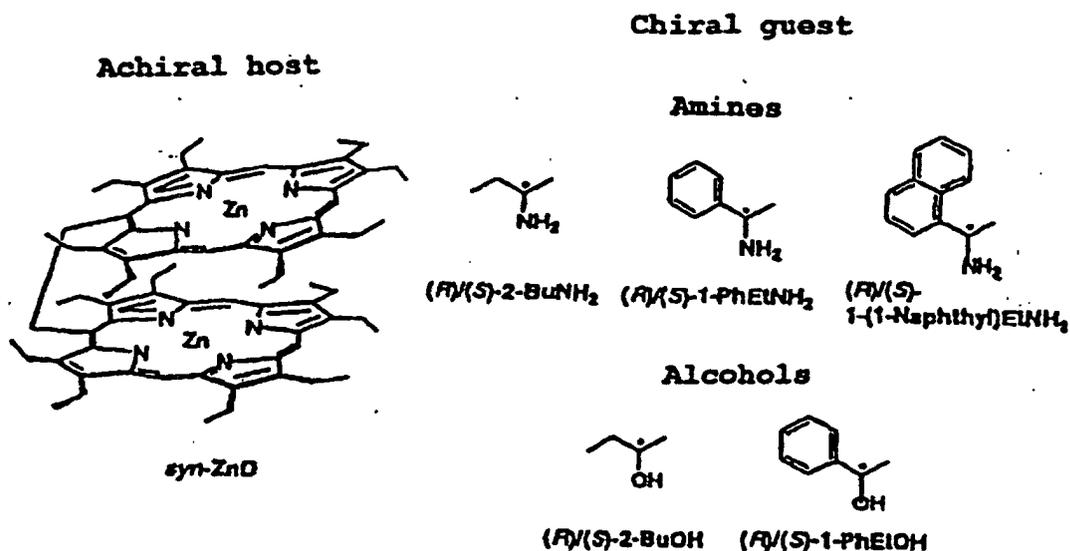
[0008] The basic principle of this determination of the absolute configuration is described below with reference to the case of zinc porphyrin represented by formula (I):



{ μ {[5,5'-(ethane-1,2-diyl)bis[2,3,7,8,12,13,17,18-octaethyl-21H,23H-porphyrinato](4-)]- κ N²¹, κ N²², κ N²³, κ N²⁴, κ N^{21'}, κ N^{22'}, κ N^{23'}, κ N^{24'}}}]dizinc.

[0009] This zinc porphyrin has a porphyrin dimer structure in which one of the porphyrin rings has two ethyl groups (-CH₂CH₃) each bonded to the second peripheral carbon atoms (b), (b) from the carbon atom (a) at the crosslink site crosslinked by an ethylene chain (-CH₂-CH₂-).

[0010] The present inventors already found that a zinc octaethylporphyrin dimer (ZnD) as above undergoes a conformational change from syn to anti upon coordination of an alcohol or an amine such as those represented by the following formulas:



[0011] Further, the inventors found that upon coordination of a chiral alcohol or a chiral amine, asymmetry is induced in the anti conformer, whereby circular dichroism is exhibited as shown in Fig. 1. The mechanism of asymmetric induction is illustrated in Fig. 2. Thus it can be understood that the porphyrins' orientation is twisted by the steric hindrance between the ethyl group (Et) of the porphyrin and the bulkiest substituent (X) bonded to the α carbon of the ligand, and the exciton interaction between the porphyrin rings produces circular dichroism.

[0012] The correlation between the absolute configuration (R-isomer or S-isomer) of a ligand and the sign of the Cotton effect is demonstrated, for example, in Table 1. Table 1 indicates that there is a correspondence between the sign of the Cotton effect and the steric configuration around the α carbon of amino or hydroxyl groups. As shown in Fig. 1, the peak occurring at a shorter wavelength shows the second Cotton effect, whereas the peak at a longer wavelength shows the first Cotton effect. The signs at the peaks may be positive or negative. For example, in the case of 1-phenylethylamine shown in Fig. 1, when the absolute configuration is (R), the second Cotton effect is positive and the first Cotton effect is negative. When the absolute configuration is (S), these signs are reversed. That is, when the first Cotton effect is positive, the absolute configuration of the chiral compound is (S). When the first Cotton effect is negative, the absolute configuration of the chiral compound is (R). Table 1 shows that this correspondence exists in many chiral compounds. These results prove that the above assumption about the mechanism of chirality induction is correct. Based on this correspondence, it is also possible to determine the absolute configuration of chemical compounds whose absolute configuration is unknown.

Table 1

Assignment of absolute configuration of chiral amines and alcohols			
Ligand	Absolute configuration and sign of ligand	Second Cotton (B_{\perp} transition)	First cotton (B_{\parallel} transition)
2-Butanol	(R)-(-)	+	-
	(S)-(+)	-	+
1-Phenylethanol	(R)-(+)	+	-

Table 1 (continued)

Assignment of absolute configuration of chiral amines and alcohols			
Ligand	Absolute configuration and sign of ligand	Second Cotton (B_{\perp} transition)	First cotton (B_{\parallel} transition)
	(S)-(-)	-	+
2-Butylamine	(R)-(-) (S)-(+)	+ -	- +
1-Phenylethylamine	(R)-(+) (S)-(-)	+ -	- +
1-(1-Naphthyl)ethylamine	(R)-(+) (S)-(-)	+ -	- +
1,2-Diaminocyclohexane	(1R,2R)-(-)	+	-
1-Amino-2-propanol	(R)-(-) (S)-(+)	+ -	- +
2-Amino-4-methyl-1-pentanol	(R)-(-) (S)-(+)	+ -	- +
1-Cyclohexylethylamine	(R)-(-) (S)-(+)	+ -	- +
N-methyl-1-phenylethylamine	(R)-(+) (S)-(-)	+ -	- +
2-Methyl-1-butylamine	(S)-(-)	-	+
Bornylamine	(1R,2S)-(+)	-	+
1,2-Diphenylethylenediamine	(1R,2R)-(+) (1S,2S)-(-)	+ -	- +

[0013] In Table 1, the B_{\parallel} transition is a transition occurring when the moments of two porphyrin rings are aligned in the direction of bonding the porphyrin rings and the resulting absorption band is B-band. The B_{\perp} transition is a transition occurring when the moments of two porphyrin rings are in directions perpendicular to the direction of bonding the porphyrin rings and the resulting absorption band is B-band (see the solid line in Fig. 3). In both the B_{\parallel} transition and the B_{\perp} transition, the directions of moments of the two porphyrin rings of a chiral porphyrin dimer are slightly misaligned with respect to each other, as compared to the achiral porphyrin dimer (see the dotted line in Fig. 3).

[0014] The metalloporphyrin used in the present invention can be synthesized by known methods (e.g., Japanese Unexamined Patent Publication No. 255790/1999).

[0015] The chiral compound whose absolute configuration can be determined by the method of the invention is, basically, a compound having an asymmetric carbon bonded to a basic group capable of coordinating to the metal on the porphyrin ring of said metalloporphyrin dimer or an asymmetric carbon adjacent to the carbon atom bonded to said basic group (i.e., an asymmetric carbon bonded to the carbon atom having the basic group).

[0016] Representative examples of such basic groups are amino and hydroxyl. More specifically, the chiral compound whose absolute configuration can be determined by the method of the present invention is a compound which forms a ligand for a metalloporphyrin. Representative examples of chiral compounds are 1) primary amines, 2) secondary amines, 3) primary diamines, 4) secondary diamines, 5) monoalcohols, and 6) aminoalcohols.

[0017] For example, all the compounds listed in Table 1 from 2-butanol to N-methyl-1-phenylethylamine correspond to chiral compounds having an asymmetric carbon bonded to a basic group capable of coordinating to the metal of the porphyrin ring. 2-methyl-1-butylamine corresponds to a chiral compound having an asymmetric carbon adjacent to the carbon atom bonded to the coordinative basic group. With respect to compounds having 2 or more asymmetric carbons such as bornylamine and diamine shown in Table 1, the absolute configuration of the asymmetric carbon bonded to the amino group coordinated to the metal of the metalloporphyrin can be determined.

[0018] In the present invention, the chiral compound capable of forming a ligand for a metalloporphyrin is coordinated to the metalloporphyrin, preferably in a non-ligand-forming solvent, and the resulting coordination compound is analyzed by CD spectrophotometry.

[0019] That is, the new method of the present invention for determining the absolute configuration of a variety of chiral compounds capable of coordination to metalloporphyrins comprises analyzing a mixed sample of a chiral compound and a metalloporphyrin in a non-ligand solvent, by circular dichroism (CD) spectrophotometry. According to this method, the absolute configuration of chiral compounds can be directly observed without the need to derive any specifically modified compounds, and the chirality of the carbon atom directly bonded to the ligand-forming group or a carbon atom adjacent to the carbon atom can be determined.

[0020] Representative examples of non-ligand solvents include halogenated aliphatic hydrocarbons such as chloroform (CHCl_3), dichloride methane (CH_2Cl_2), dichloride ethane ($\text{CH}_2\text{ClCH}_2\text{Cl}$), tetrachloride ethane ($\text{CHCl}_2\text{CHCl}_2$), carbon tetrachloride (CCl_4) and the like, and aliphatic hydrocarbons such as hexane, heptane and the like.

[0021] In the method of the present invention, samples to be analyzed by CD spectrophotometry can be prepared, for example, in the following manner:

[0022] A chiral compound and a metalloporphyrin are dissolved in said solvent. The concentrations of the chiral compound and the metalloporphyrin are not critical. Generally, the concentration of the chiral compound should be 10^{-4} mol/l or higher, and the concentration of the metalloporphyrin 10^{-6} mol/l or higher. Their concentrations can suitably be selected from the above ranges in accordance with the type of solvent used, etc.

[0023] In the case of the metalloporphyrin of formula (1), the minimum concentrations of chiral compounds required for observing sufficient Cotton effects are as follows: primary acyclic monoamines preferably have a minimum concentration of about 10^{-3} mol/l, cyclic aromatic monoamines about 10^{-4} mol/l, secondary amines about 10^{-4} mol/l, diamines about 10^{-3} mol/l and aminoalcohols about 10^{-3} mol/l. Preferably, the minimum concentration of monoalcohols required for observing sufficient Cotton effects is about 10^{-1} mol/l and the temperature is -80°C .

[0024] The following cases 1-5 can be mentioned as examples.

[Case 1]

[0025] The absolute chirality of primary monoamines can preferably be determined when the minimum concentration thereof in chloroform, dichloromethane, carbon tetrachloride, tetrachloroethane, hexane or heptane is adjusted to about 10^{-4} mol/l to 10^{-3} mol/l and the concentration of the metalloporphyrin of formula (I) is about 10^{-6} mol/l. Examples of primary monoamines include 2-butylamine, 1-phenylethylamine, 1-(1-naphthyl)ethylamine, 1-cyclohexylethylamine, 2-methyl-1-butylamine, and [endo-(1R)-1,7,7-trimethylbicyclo[2,2,1]heptan-2-amine].

[Case 2]

[0026] The absolute chirality of secondary monoamines can preferably be determined when the minimum concentration thereof in chloroform, dichloromethane, carbon tetrachloride, tetrachloroethane, hexane or heptane is adjusted to about 10^{-4} mol/l and the concentration of the metalloporphyrin of formula (I) is about 10^{-6} mol/l. Examples of secondary monoamines include N-methyl-1-phenylethylamine.

[Case 3]

[0027] The absolute chirality of diamines can preferably be determined when the minimum concentration thereof in chloroform, dichloromethane, carbon tetrachloride, tetrachloroethane, hexane or heptane is adjusted to about 10^{-3} mol/l and the concentration of the metalloporphyrin of formula (I) is about 10^{-6} mol/l. Examples of diamines include 1,2-diphenylethylenediamine and 1,2-diaminocyclohexane.

[Case 4]

[0028] The absolute chirality of aminoalcohols can preferably be determined when the minimum concentration thereof in chloroform, dichloromethane, carbon tetrachloride, tetrachloroethane, hexane or heptane is adjusted to about 10^{-3} mol/l and the concentration of the metalloporphyrin of formula (I) is about 10^{-6} mol/l. Examples of aminoalcohols include 1-amino-2-propanol and 2-amino-4-methyl-1-pentanol.

[Case 5]

[0029] The absolute chirality of monoalcohols can preferably be determined when the minimum concentration thereof is adjusted to about 10^{-1} mol/l and the concentration of the metalloporphyrin of formula (I) is about 10^{-6} mol/l in dichloromethane or hexane at -80°C . Examples of monoalcohols include 2-butanol and 1-phenylethanol.

[0030] The present invention enables precise and easy determination of the absolute configuration of chiral compounds having a wide variety of basic groups bonded thereto. That is, the method of the invention can precisely and

easily determine the absolute configuration of the chiral compounds having an asymmetric carbon directly bonded to a coordinative basic group or an asymmetric carbon adjacent to the carbon atom bonded to the basic group. More specifically, the method of the present invention achieves the following excellent effects:

- 1) The absolute chirality of various optionally active compounds can be directly observed.
- 2) Only trace amounts of samples, i.e., metalloporphyrin (at the level of μg) and chiral compounds (amines (μg), alcohols (mg)) are needed.
- 3) Since no chemical change occurs, the samples can be recovered easily, if necessary.
- 4) Determination of absolute chirality is very fast. Preparation of the samples and measurement of the CD spectra can be done in 10 minutes.
- 5) The detection of Cotton effects is usually carried out in the region of 400 to 450 nm, while most chiral compounds have absorptions up to 400 nm. Therefore, a wide variety of compounds can be analyzed.
- 6) The chiral compounds can be used without the need to derive any specifically modified compounds.
- 7) The absolute chirality of non-crystalline compounds can be determined.

BEST MODE FOR CARRYING OUT THE INVENTION

[0031] The present invention will be described below in further detail with reference to an Example.

Example 1

[0032] A CH_2Cl_2 solution containing about 10^{-6} mol/l of zinc porphyrin of formula (I) and about 10^{-4} mol/l of (R)-(-)-1-cyclohexylamine was prepared in a 3 ml cell, and the circular dichroism spectra were observed in the region of 350 nm to 500 nm at room temperature. Fig. 4 shows the results.

[0033] The absolute configuration of a chiral compound is determined from the sign of the first Cotton effect at a longer wavelength. From the negative sign of the first Cotton effect as shown in Fig. 4, the absolute configuration of (R)-(-)-1-cyclohexylethylamine was confirmed to be (R).

[0034] Similarly, a CH_2Cl_2 solution containing about 10^{-6} mol/l of the zinc porphyrin and about 10^{-1} mol/l of (R)-(-)-1-phenylethanol was prepared in a 3 ml cell, and the circular dichroism spectra were observed in the region of 350 nm to 500 nm at -80°C . Fig. 5 shows the results.

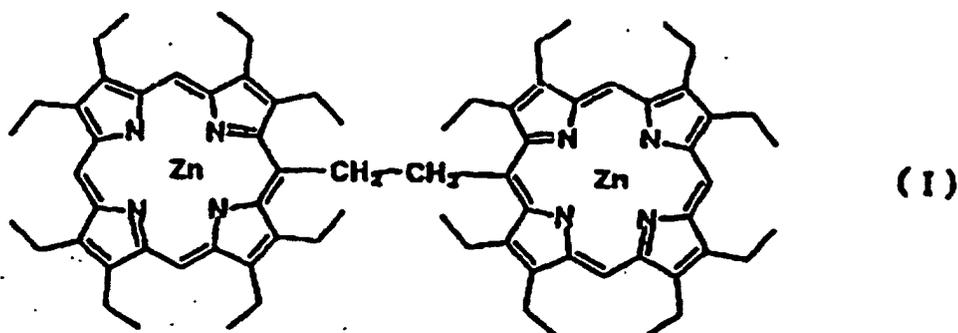
[0035] In this case also, the sign of the first Cotton effect was negative. Thus the absolute configuration of the chiral compound was confirmed to be (R).

[0036] The method of the present invention determines the absolute configuration of chiral compounds in the manner described above. The effectiveness of this method was also confirmed for the assignment of the absolute configuration of chiral amines and alcohols as shown in Table 1.

Claims

1. A method for determining the absolute configuration of a chiral compound which comprises:

coordinating the chiral compound to a metalloporphyrin represented by the following formula (I):



$\{\mu\{\{5,5'-(\text{ethane-1,2-diyl})\text{bis}[2,3,7,8,12,13,17,18\text{-octaethyl-21H,23H-porphyrinato}]\{4-\}\} - \kappa\text{N}^{21}, \kappa\text{N}^{22}, \kappa\text{N}^{23}, \kappa\text{N}^{24}, \kappa\text{N}^{21'}, \kappa\text{N}^{22'}, \kappa\text{N}^{23'}, \kappa\text{N}^{24'}\}\}\text{dizinc};$

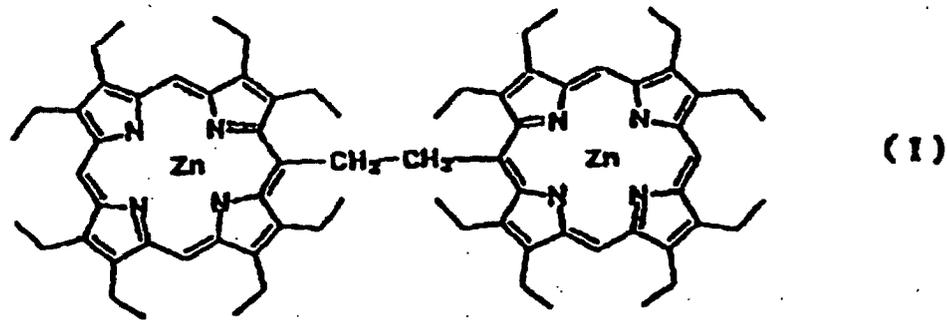
the chiral compound having an asymmetric carbon bonded to a basic group capable of coordinating to the metal of the porphyrin ring of the metalloporphyrin or an asymmetric carbon atom adjacent to the carbon atom bonded to the basic group; and
 analysing the resultant coordination compound by circular dichroism spectrophotometry to determine the absolute configuration of the asymmetric carbon of the chiral compound based on the sign of the Cotton effect.

2. The method according to claim 1 wherein the chiral compound is a primary amine, a secondary amine, a primary diamine, a secondary diamine, a monoalcohol, or an aminoalcohol.

Patentansprüche

1. Verfahren zur Bestimmung der absoluten Konfiguration einer chiralen Verbindung, welches umfasst:

Koordinieren der chiralen Verbindung an ein durch die folgende Formel (I) dargestelltes Metalloporphyrin:



$\{\mu\{5,5'-(\text{Ethan-1,2-diyl})\text{bis}[2,3,7,8,12,13,17,18\text{-octaethyl-21H,23H-porphyrinato}]\{4-\}\} - \kappa\text{N}^{21}, \kappa\text{N}^{22}, \kappa\text{N}^{23}, \kappa\text{N}^{24}, \kappa\text{N}^{21'}, \kappa\text{N}^{22'}, \kappa\text{N}^{23'}, \kappa\text{N}^{24'}\}\}$ dizink;

wobei die chirale Verbindung einen asymmetrischen Kohlenstoff, der an eine basische Gruppe gebunden ist, die in der Lage ist, an das Metall des Porphyrinrings des Metalloporphyrins zu binden, oder ein asymmetrisches Kohlenstoffatom, das zu dem Kohlenstoffatom benachbart ist, das an die basische Gruppe gebunden ist, aufweist, und

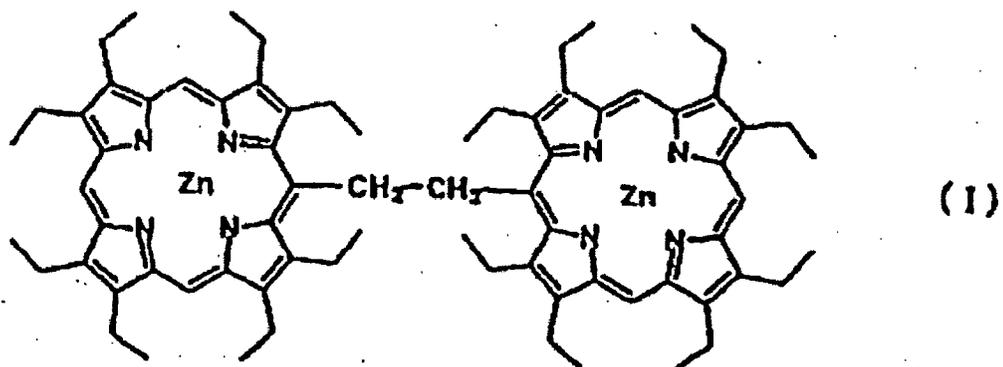
Analysieren der sich ergebenden Koordinationsverbindung durch Zirkulardichroismus-Spektralphotometrie zur Bestimmung der absoluten Konfiguration des asymmetrischen Kohlenstoffs der chiralen Verbindung auf Basis des Vorzeichens des Cotton-Effekts.

2. Verfahren nach Anspruch 1, worin die chirale Verbindung ein primäres Amin, ein sekundäres Amin, ein primäres Diamin, ein sekundäres Diamin, ein Monoalkohol oder ein Aminoalkohol ist.

Revendications

1. Méthode de détermination de la configuration absolue d'un composé chiral qui comprend :

la coordination du composé chiral à une métalporphyrine représentée par la formule (I) suivante :



15 $\{\mu\{5,5'-(\text{éthane-1,2-diyl})\text{bis}[2,3,7,8,12,13,17,18\text{-octaéthyl-21H,23H-porphyrinato}](4-)-\text{kN}^{21}, \text{kN}^{22}, \text{kN}^{23}, \text{kN}^{24}, \text{kN}^{21'}, \text{kN}^{22'}, \text{kN}^{23'}, \text{kN}^{24'}\}\}$ dizinc ;

le composé chiral ayant un carbone asymétrique lié à un groupe basique capable de coordination au métal du cycle porphyrine de la métalloporphyrine ou un atome de carbone asymétrique adjacent à l'atome de carbone lié au groupe basique ; et

l'analyse du composé de coordination résultant par une spectrophotométrie à dichroïsme circulaire pour déterminer la configuration absolue du carbone asymétrique du composé chiral sur la base du signe de l'effet de Cotton.

2. Méthode selon la revendication 1, dans laquelle le composé chiral est une amine primaire, une amine secondaire, une diamine primaire, une diamine secondaire, un monoalcool ou un aminoalcool.

Fig. 1

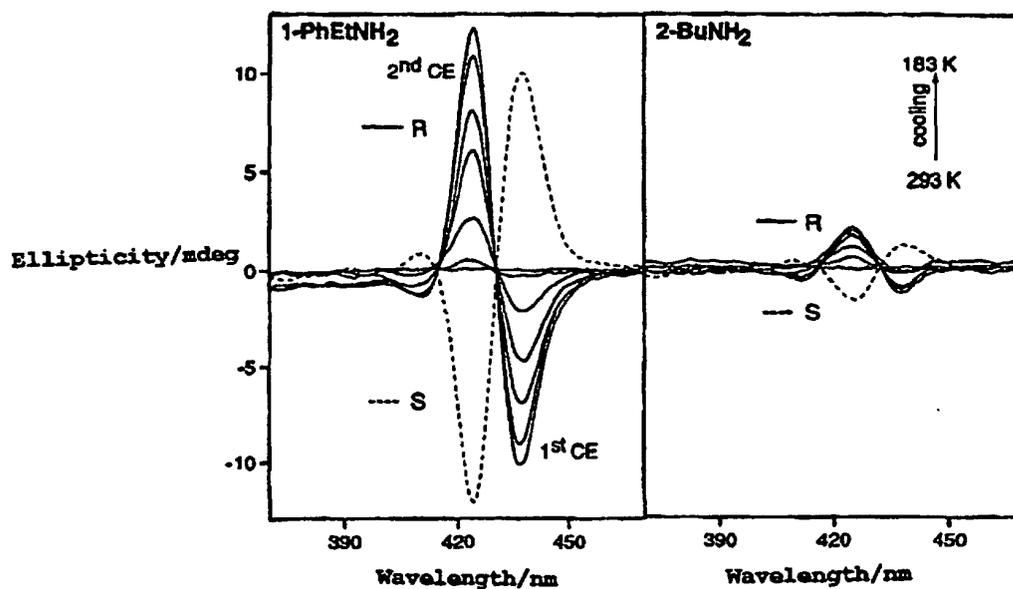


Fig. 2

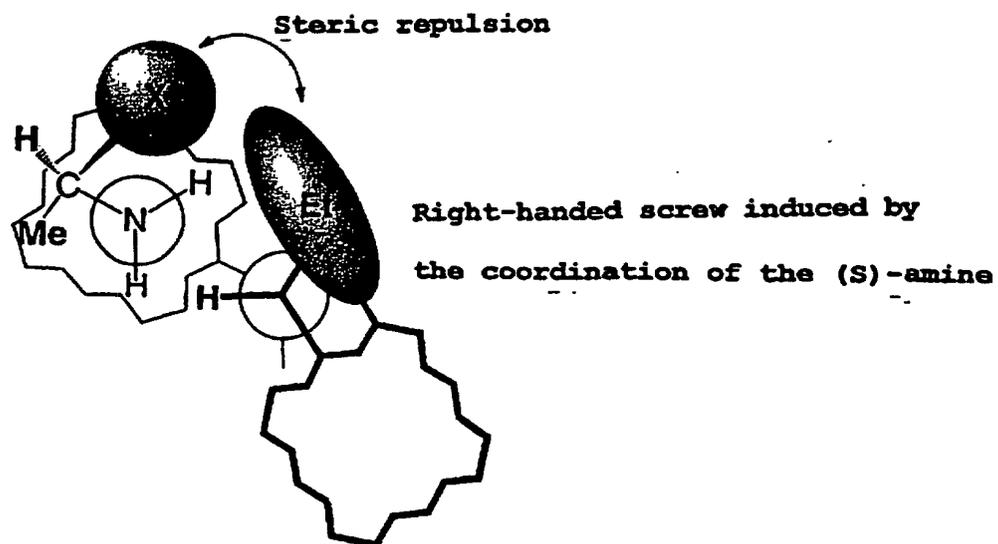
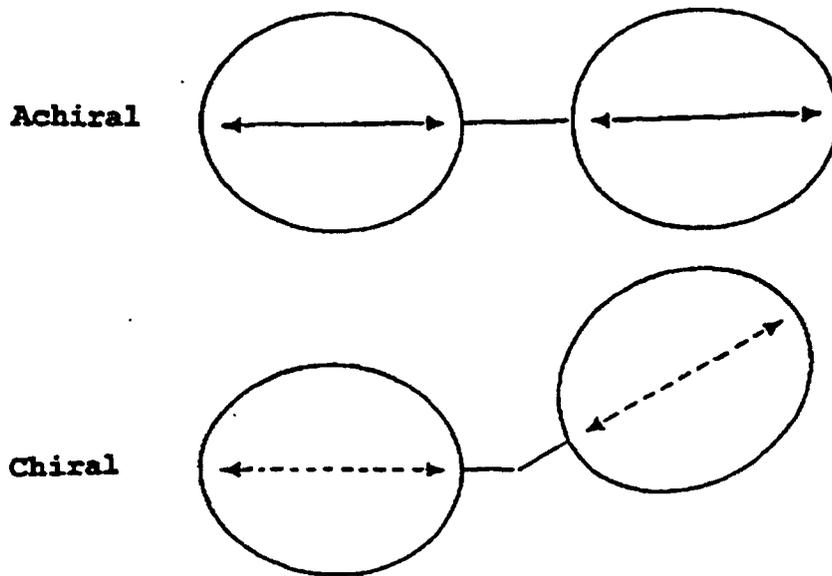


Fig. 3

$B \parallel$;



$B \perp$;

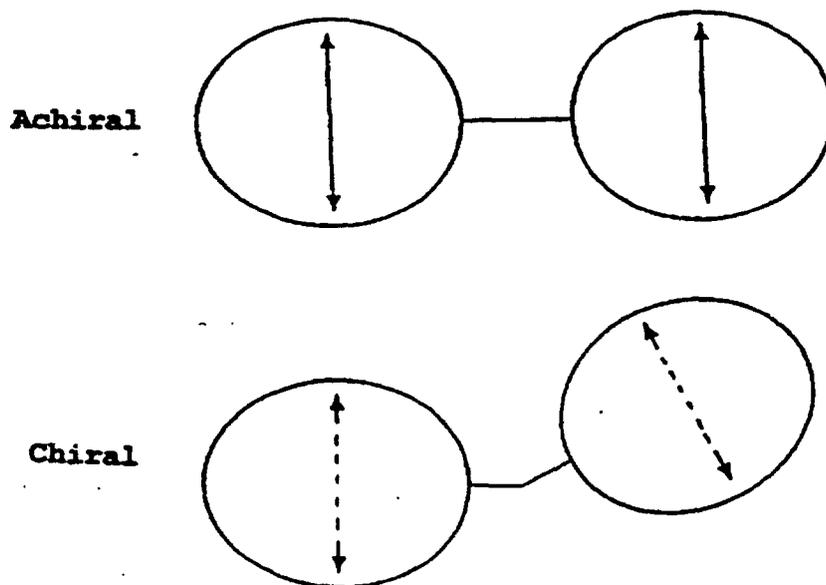


Fig. 4

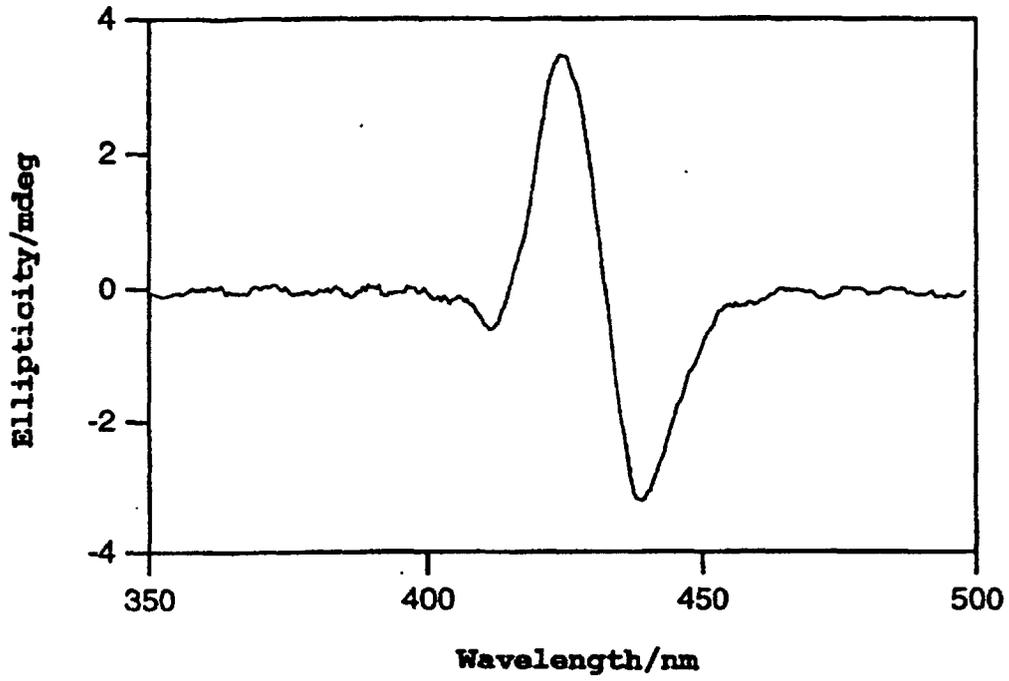


Fig. 5

