New complexanes. XXXIV. Preparation and properties of the *meso* and *rac* forms of ethylenediamine-*N*,*N*′-disuccinic acid

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The coordination of the stereoisomeric chelating ligands is utilized as an alternative way how to obtain selective analytical titration agents. A nucleophilic addition of ethylenediamine on sodium maleate yielded a mixture of stereoisomers of ethylenediamine-*N*,*N*′-disuccinic acid from which the *meso* and *rac* forms were successfully separated *via* their copper(II) complexes. The obtained compounds were characterized by their i.r. spectra. From the crystallographic measurements it was unambiguously determined which of the isolated forms is the racemic modification.

Одно из направлений получения селективных аналитических реагентов для титрования состоит в использовании координации стереоизомерных хелатообразующих лигандов. При нуклеофильном присоединении этилендиамина на натриевую соль малеиновой кислоты образуется смесь стереоизомеров этилендиамин-*N*,*N*′-диянтарной кислоты, которую удалось при помощи комплексных соединений меди разделить на *мезо* и *рац* формы. Полученные вещества характеризуются инфракрасными спектрами. На основании кристаллографических данных можно было однозначно идентифицировать рацемическую модификацию.

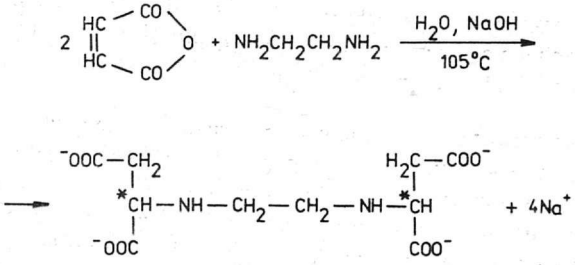
The aim of the present development of the multidentate ligands derived from amino polycarboxylic acids, *i.e.* analytical agents — complexanes, is to achieve the highest possible selectivity of the complexing reaction with metal ions. It can be attained either through a proper choice of the donor atoms or by creating a ligand with such spatial arrangement which is best suited for the central metal with respect to its ionic radius and the number and directional orientation of its bonds. In the solution, the spatial arrangement and thermodynamic stability of the complexes of ligands with several chiral centres is affected by the absolute configuration of the individual chiral centres [1].

Ethylenediamine-*N*,*N*′-disuccinic acid (EDDS) belongs to the series of chelating agents derived from natural amino acids [2—5]. From the chemically very similar isomeric EDTA it differs by the presence of two chiral centres. Thus EDDS occurs in three stereoisomers, (*S*,*S*), (*R*,*S*), and (*R*,*R*). *Majer et al.* [2] synthesized (*S*,*S*)-EDDS and the stability constants of its complexes were determined potentiometrically [6]. *Kezerian* and *Ramsey* [7] patented another synthesis of EDDS, different from that of Majer et al., however, they were unaware that they did not obtain a chemical individuum but a mixture of three isomers. In this work, their synthesis was revised and *meso*-EDDS was obtained as a potential new chelating agent.

Experimental

Preparation of the mixture of EDDS isomers

EDDS was obtained by a modified procedure of *Kezerian* and *Ramsey* [7] (Scheme 1). The asymmetric carbon is formed by a nucleophilic addition of the amino group on the



Scheme 1

double bond. As far as the orientational effect of the first chiral centre does not influence binding the second maleic unit to the product of the half condensation, then, for the statistical reasons, 25% (*R*,*R*)-EDDS, 25% (*S*,*S*)-EDDS, and 50% *meso*-EDDS should be formed.

Procedure

Water (400 ml) is poured to anhydride of maleic acid (400 g; 4 moles) and the suspension is allowed to stay for 1 h with occasional stirring. The solution of NaOH (350 g) in water (350 ml) is then slowly added into the suspension of the anhydride. The reaction is very energetic and cooling is required to maintain the temperature of the reaction mixture at 75—85°C. Ethylenediamine (119 g; 2 moles) is added to the formed solution which is then refluxed for 48 h. When the reaction is finished, the hot solution is filtered, diluted by water

up to fourfold volume, and neutralized by diluted HCl (1:1) to pH 7. The deposited impurities are filtered off. The solution is acidified by diluted HCl (1:3) to pH 3 under vigorous stirring at 0°C. The deposited EDDS is purified by the repeated precipitation and massive washing with water.

Separation of the mixture

The different solubility of the *meso* and *rac* forms in water was utilized for their crude separation though the aqueous solubility of both of them is very small (at 20°C less than 0.2 g l^{-1}). The product of the synthesis was suspended in water at 80°C (EDDS decarboxylates spontaneously above 90°C), the suspension shortly stirred and immediately filtered. The more soluble form, denoted *A*, was preferably transferred into the solution while the enriched *B* form was left on the filter. The enriched forms were allowed to react with an excess of basic copper(II) carbonate. The formed complexes Cu:EDDS = 2:1 are well soluble in water at 80°C and the complex formation prevents the decarboxylation of EDDS. On cooling the saturated solutions, the complex of the substance *A* is deposited in the form of crystals in contrast to the substance *B* the complex of which gives only fine crystalline precipitate. The copper(II) complexes can be thus easily separated by the flotation and purified by the recrystallization. The pure complexes are dissolved in water, copper is precipitated by Na_2S, and after removing sulfides and the colloidal sulfur the pure acids are isolated by acidifying the solution by diluted HCl. The form *A* may be recrystallized from water, at lower temperature as EDDS-*A* · $5H_2O$. At higher temperature, after longer stay or by inocculating the solution, the flock-like anhydrous EDDS-*A* quickly precipitates, as soon as the crystallizing nuclei are formed. Anhydrous EDDS-*A* is very poorly soluble in water and therefore its formation hinders an unambiguous separation of the two forms by the fractional crystallization from water. EDDS-*A* can be transformed into the more soluble EDDS-*A* · $5H_2O$ through the reprecipitation at low temperature.

For $C_{10}N_2H_{16}O_8$ (292.2) calculated: 41.11% C, 9.58% N; found (EDDS-*A*): 41.10% C, 9.38% N; found (EDDS-*B*): 40.82% C, 9.48% N.

For $C_{10}N_2H_{26}O_{13}$ (382.3) calculated: 31.42% C, 7.33% N; found: 31.29% C, 7.30% N.

Crystallographic data

Through slow cooling the EDDS-*A* solution we succeeded to gain monocrystals of EDDS-*A* · $5H_2O$ large enough for the X-ray examination. The basic crystallographic data were determined by the Weissenberg technique. The crystal density was determined by the flotation method in the ethanol—dibromoethane mixture. From the systematic extinction of the diffraction spots, the space group of symmetry was unambiguously determined. The following results were obtained

$a = 1.13$ nm	$\varrho_{exp} = 1400$ kg m^{-3}
$b = 1.43$ nm	$\varrho_{calc} = 1420$ kg m^{-3}
$c = 0.55$ nm	$Z = 2$
$V = 0.890$ nm^3	space group $P2_12_12$

Infrared spectra

The i.r. spectra were measured with a Perkin—Elmer spectrophotometer, Model 377, in the range $4000-400\ cm^{-1}$ by the method of KBr pellets.

Results and discussion

In the space group $P2_12_12$ the general position is 4, however, only two EDDS-*A* molecules are present in a unit cell. Thus there is one half of the molecule in a symmetrically independent part of the unit cell, *i.e.* one asymmetric centre. Neither the centre nor the symmetry plane exist in the space group $P2_12_12$, only the twofold axes and, therefore, all the asparagic units of a particular monocrystal must be of the same absolute configuration. This can be met only if EDDS-*A* is the racemic modification and EDDS-$A \cdot 5H_2O$ the racemic mixture. The identical chemical composition and crystallographic data pointed out the same crystal structure of (*S,S*)-EDDS$\cdot 5H_2O$ [8] and *rac*-EDDS$\cdot 5H_2O$.

The i.r. spectrum of the anhydrous *rac*-EDDS differs considerably from the spectrum of (*S,S*)-EDDS$\cdot 5H_2O$ described by *Neal* and *Rose* [9]. *rac*-EDDS exhibits three significant bands with maxima at 1670, 1545, and $1480\ cm^{-1}$, respectively. The $1545\ cm^{-1}$ band corresponds to the asymmetrical stretching vibration of the COO^- group and the $1670\ cm^{-1}$ band is probably composed of two vibrational transitions, namely C=O in COOH and the deformational vibration of the NH_2^+ group. *meso*-EDDS exhibits a splitted band at 1723 and $1704\ cm^{-1}$ assigned to the C=O vibration in COOH, the 1630—1605 cm^{-1} band corresponds to the deformational NH_2^+ vibration, and the $1570\ cm^{-1}$ band to the asymmetrical stretching vibration of the COO^- group. Both the *meso* and *rac* forms have in their i.r. spectra the $1400\ cm^{-1}$ band which corresponds to the symmetrical stretching vibration of the COO^- group. The reason for the shift and mutual overlap of the bands, in comparison with (*S,S*)-EDDS$\cdot 5H_2O$, may be a different kind of hydrogen bonds. While in (*S,S*)-EDDS$\cdot 5H_2O$ they occur partly between the acid and water molecules, in the anhydrous forms only between the functional groups of acids.

The structural character of the anhydrous *rac*-EDDS is not quite apparent. However, a comparison with the behaviour of the (*S,S*)-EDDS solutions from which no anhydrous form precipitates at higher temperature as well as the unwillingness of *rac*-EDDS to form crystallizing nuclei indicate that, in contradistinction to *rac*-EDDS$\cdot 5H_2O$, *rac*-EDDS is a racemic compound.

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