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Preliminary Note**On the Stability of Metal Complexes with Racemic Ligands**

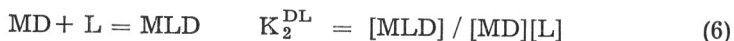
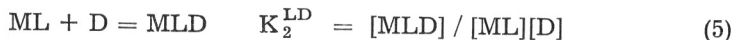
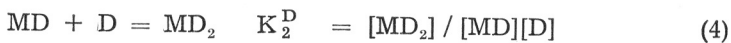
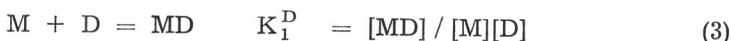
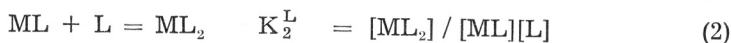
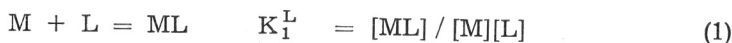
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Although the amino-acid chelates have been extensively investigated on account of their stability, most of the work was done without regard to the optical properties of such ligands¹. The same also applies to optically active ligands other than amino-acids. Before trying to elucidate the experimental evidence this communication was originated with the question: can useful evaluation of stability data be made in systems consisting of a metal ion and racemic or enantiomeric forms of an optically active ligand.

For a metal ion M in equilibrium with a racemic ligand DL or its enantiomers D and L the following fundamental equations can be written (charges are omitted for the sake of clarity):



The over-all stoichiometric stability constants of the simple and mixed complexes can be defined by:

$$\beta_2^L = [ML_2] / [M][L]^2 = K_1^L K_2^L \quad (7)$$

$$\beta_2^D = [MD_2] / [M][D]^2 = K_1^D K_2^D \quad (8)$$

$$\beta_2^{LD} = [MLD] / [M][L][D] = K_1^L K_2^{LD} = K_1^D K_2^{DL} \quad (9)$$

The above expressions can be written by making the following assumptions: (1) systems are mononuclear with respect to M , and (2) the number of ligands per one metal ion does not exceed 2, *i.e.* the reaction of a metal M with a ligand L , or D gives rise to a series of complexes: ML , MD , ML_2 , MD_2 and/or MLD .

From eq. (9) a new constant, K_m , can be derived:

$$K_1^D / K_1^L = K_2^{LD} / K_2^{DL} = K_m \quad (10)$$

which represents the equilibrium of the metathetic reaction



and is a measure for the relative affinity of the metal towards the *L*- and *D*-forms of the ligand, respectively.

When determining the stability constants in such a system experimentally, apparent stability constants are obtained:

$$K_{1, \text{app.}}^{\text{LD}} = \{[ML] + [MD]\} / [M]\{[L] + [D]\} \quad (12)$$

$$\beta_{2, \text{app.}}^{\text{LD}} = \{[ML_2] + [MD_2] + [MLD]\} / [M]\{[L] + [D]\}^2 \quad (13)$$

It can easily be shown that in such calculations the composite degree of formation, \bar{n} , and free ligand exponent, pX , are obtained. They are defined as follows:

$$\bar{n} = \bar{n}_L + \bar{n}_D \quad (14)$$

$$pX = p\{[L] + [D]\} \quad (15)$$

Eqs. (7) — (9) can be substituted into (13) and a general expression is then obtained:

$$\beta_{2, \text{app.}}^{\text{LD}} = \frac{\beta_2^L \frac{[L]}{[D]} + \beta_2^{\text{LD}} + \beta_2^D \frac{[D]}{[L]}}{\frac{[L]}{[D]} + 2 + \frac{[D]}{[L]}} \quad (16)$$

If $\beta_{2, \text{app.}}^{\text{LD}}$, β_2^L , β_2^D and $[L]/[D]$ are known, β_2^{LD} can be readily calculated from eq. (16).

In the special case, when $\beta_2^L = \beta_2^D = \beta_2$, and $[L] = [D]$, eq. (16) reduces to

$$\beta_{2, \text{app.}}^{\text{LD}} = \frac{2\beta_2 + \beta_2^{\text{LD}}}{4} \quad (17)$$

Bennett² has deduced a relation between K_2^L and $K_{2, \text{app.}}^{\text{LD}}$ assuming that the affinities of copper complexes with enantiomeric forms of asparagine are equal ($[\text{CuL}_2] = [\text{CuD}_2]$, $[\text{CuL}] = [\text{CuD}]$, $[L] = [D]$). His relation in our notation becomes:

$$K_2^{\text{LD}} = 2K_{2, \text{app.}}^{\text{LD}} - K_2 \quad (18)$$

If Bennett's assumptions are valid, they imply the equality of the over-all stability constants as well as the equality of successive stability constants.

Fronaeus³ has investigated the copper tartarate system and determined following stability data:

	$\log K_1$	$\log K_2$	$\log \beta_2$	$\log K_3$	$\log K_4$	$\log \beta_4$
(+)-tartaric acid	3.20	1.91	5.11	-0.34	1.73	6.50
<i>rac</i> -tartaric acid	3.00	2.11	5.11	0.65	0.44	6.20

Because $\beta_4 - \beta_2$ is about one *log* unit only, it seems to be possible — as a first approximation — to neglect the formation of species containing more than two ligands. By considering these data it can be observed that $K_{1, \text{app.}}^{\text{LD}} \neq K_{-}$ and $K_{2, \text{app.}}^{\text{LD}} \neq K_2^{\text{D}}$. As far as we know the stability data for copper-(-)-tartarate complexes have not been published and it would therefore appear incautious to substitute Fronaeus' data in eqs. (17) or (18) without giving due consideration to the meaning of the results obtained. The same applies to results published by Bennett whose experimental data are also not sufficient for such a treatment.

Furthermore, it will be noted that there is an inconsistency in Bennett's interpretation of his final equation: if the affinities of both ligand species (*L* and *D*) towards *M* are really equal, then all three *bis*-asparaginato copper species (ML_2 , MD_2 , and MLD) do exist in the system in certain proportions. It is difficult to think of the non-existence of the mixed species (MLD) since this would not be in agreement with eq. (10) in the case when $K_1^{\text{L}} = K_1^{\text{D}}$. It follows from eq. (10) that in such a case K_m is equal to unity. The non-existence of the MLD species requires K_2^{LD} or K_2^{DL} to be zero, and consequently the value of zero or ∞ , respectively, would be obtained for K_m^* .

Therefore, it seems that — when determining the stabilities of metal complexes of optically active ligands — it is always necessary to state whether the work was done with the racemic or one of the enantiomeric forms of the ligand. The conclusions about the stability of mixed complexes of this type can be wrong if a detailed examination of the systems under consideration has not been made.

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IZVOD

O stabilnosti kompleksa metala s racemičnim ligandima

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Razmotrena je ravnoteža u otopini koja sadrži ione metala (*M*) i oba enantiomerna oblika nekoga optički aktivnog liganda (*L* i *D*). Uz pretpostavku da u sistemu nastaju kompleksne vrste ML , MD , ML_2 , MD_2 i MLD izveden je opći izraz koji povezuje konstante stabilnosti tih vrsta s prividnom konstantom stabilnosti kakva se eksperimentalno određuje.

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* The abrupt formation of MLD ($K_2^{\text{LD}} = K_2^{\text{DL}} = 0$, $\beta_2^{\text{LD}} > 0$) was not considered here, supposing that such a case would be a highly improbable one.