The Quadratic forms of Equations for Calculation of the $K_i$ and $K_a$ Constants of Enzyme Inhibition and Activation

Krupyanko VI*

GK Skryabin Institute of Biochemistry and Physiology of Microorganism, Russian Academy of Sciences, Russia

*Corresponding author: Krupyanko VI, GK Skryabin Institute of Biochemistry and Physiology of Microorganism, Russian Academy of Sciences, 142290 Pushchino, Moscow region, prospect Nauki 5Postal address: town Pushchino, Prospekt Nauki 5, Moscow region, Russia

Introduction

In previous articles [1-9], devoted to construction of a vector method representation of enzymatic reactions in the three-dimensional $K_i,V'/I$ coordinate system the properties of L vectors of enzymatic reactions was analyzed, from which the parametrical classification of the types of enzymatic reactions and the equations for calculation of initial activated ($V_a$) and inhibited ($V_i$) reaction rates was suggested. In these article the equations of traditional form (t.f.) for calculation of the constants of activation ($K_a$) and absent in practice nontrivial types of biparametrical constants of inhibition ($K_i$) of enzymes (Table 1), was deduced.

This work is devoted to deduction of quadratic form (q.f.) of the equations for calculation of biparametrical constants of inhibition and activation of enzymes (Table 1t & 1f), opening additional ability in the analysis of enzyme action which help of quadratic forms of equation (Table 1q& 1f).

The examples of comparative using traditional and quadratic form of equations for calculation of $K_i$ and $K_a$ constants of inhibition and activation are given.

Deduction of Traditional form of Equations

From (Figures 1, 1a and 2) it easy to see, that ($I_i$) length of ($L_i$) vector of biparametrical inhibited and activated ($L_{ai}$) enzymatic reactions from the length projection of vectors of monoparametrical inhibited and activated enzymatic reactions on the basic $\sigma_0$ plane in three-dimensional $K_i,V'/I$ coordinate system, allows to deduct the quadratic forms of equations for the calculation of the constants of inhibition ($K_i$) and activation ($K_a$) of enzymes. Examples of calculation of constants are given.
**Table 1:** Equations for calculation of $K_i$ and $K_a$ constants (in traditional form).

| No | Effect | Type of effect | Correlation between $K_i$ and $V'$ parameters | Graphs in $(V'_i, x^i)$ coordinates |
|----|--------|----------------|-----------------------------------------------|-----------------------------------|
| 1  | $I_i$  | $K_m > K_m^0, V' < V^0$ | ![Graph](image1) |
| 2  | $I_i$  | $K_m < K_m^0, V' < V^0$ | ![Graph](image2) |
| 3  | III$_i$ | $K_m = K_m^0, V' < V^0$ | ![Graph](image3) |
| 4  | IV$_i$ | $K_m > K_m^0, V' = V^0$ | ![Graph](image4) |
| 5  | $V_i$ | $K_m > K_m^0, V' > V^0$ | ![Graph](image5) |
| 6  | $V_i$ | $K_m < K_m^0, V' < V^0$ | ![Graph](image6) |
| 7  | VII$_i$ | $K_m < K_m^0, V' < V^0$ | ![Graph](image7) |
| 8  | None | $K_m = K_m^0, V' = V^0$ | ![Graph](image8) |
| 9  | VII$_a$ | $K_m > K_m^0, V' > V^0$ | ![Graph](image9) |
| 10 | $V_a$ | $K_m > K_m^0, V' > V^0$ | ![Graph](image10) |
| 11 | $V_a$ | $K_m < K_m^0, V' < V^0$ | ![Graph](image11) |
| 12 | IV$_a$ | $K_m < K_m^0, V' = V^0$ | ![Graph](image12) |
| Table 1 (continuation). |
|-------------------------|

| Type of effect | New name of nzymatic reactions | Traditio-nal name | Traditional form (t.f) of equation for calculation of $K_i$ and $K_a$ constants | Quadratic form (q.f) of equations |
|----------------|-------------------------------|------------------|-------------------------------------------------|----------------------------------|
| $I_i$          | Biparame-Trically coordi-na ted inhibition | Mixed Inhibition | $K_{ii} = i \left( \frac{K_m - K_0}{K_m} \right)^2 + \left( \frac{V^0 - V}{V} \right)^2$ | $K_{ii} = 1/\left( \frac{1}{K_{ii}^2} + \frac{1}{K_{ia}^2} \right)^{0.5}$ |
| $I_i$          |  Unassosi-ative Inhibition | Uncoo-m-petitive Inhibition | $K_{iii} = i \left( \frac{K_m - K_0}{K_m} \right)^2 + \left( \frac{V^0 - V}{V} \right)^2$ | $K_{iii} = 1/\left( \frac{1}{K_{iii}^2} + \frac{1}{K_{ia}^2} \right)^{0.5}$ |
| $III_i$        | Catalytic Inhibition | Noncom-pe-titive Inhibition | $K_{iii} = i \left( \frac{K_m - K_0}{K_m} \right)^2 + \left( \frac{V^0 - V}{V} \right)^2$ | $K_{iii} = 1/\left( \frac{1}{K_{iii}^2} + \frac{1}{K_{ia}^2} \right)^{0.5}$ |
| $IV_i$         | Associa-tive Inhibition | Competitive inhibition | $K_{ii} = \frac{i}{K_m / K_0 - 1} = \frac{i}{K_m - K_0 / K_m}$ | $K_{ii} = K_{iV}$ |
| $V_i$          | Pseudoin-Hibition            |                   | $K_{ii} = i \left( \frac{K_m - K_0}{K_m} \right)^2 + \left( \frac{V - V^0}{V^0} \right)^2$ | $K_{ii} = 1/\left( \frac{1}{K_{ii}^2} + \frac{1}{K_{ia}^2} \right)^{0.5}$ |
| $V_i$          | Discoordi-nated Inhibition   |                   | $K_{ii} = i \left( \frac{K_0 - K_m}{K_m} \right)^2 + \left( \frac{V^0 - V}{V} \right)^2$ | $K_{ii} = 1/\left( \frac{1}{K_{ii}^2} + \frac{1}{K_{ia}^2} \right)^{0.5}$ |
| $VII_i$        | Transient Inhibition         |                   | $K_{iV} = i \left( \frac{K_0 - K_m}{K_m} \right)^2 + \left( \frac{V^0 - V}{V} \right)^2$ | $K_{iV} = 1/\left( \frac{1}{K_{iV}^2} + \frac{1}{K_{ia}^2} \right)^{0.5}$ |
| $VII_i$        | Initial (i = 0 and a = 0) Enzymatic Reaction | | $K_{iV} = a \left( \frac{K_m - K_0}{K_m} \right)^2 + \left( \frac{V^0 - V}{V} \right)^2$ | $K_{iV} = 1/\left( \frac{1}{K_{iV}^2} + \frac{1}{K_{ia}^2} \right)^{0.5}$ |
Table 1: 

| Activation Type | Formula | Description |
|-----------------|---------|-------------|
| Discoordinated Activation | $K_{f/a} = a / \left( \left( \frac{K_m - K_0}{K_m} \right)^2 + \left( \frac{V - V^0}{V^0} \right)^2 \right)^{0.5}$ | 
| $K_{i/a} = 1 / \left( \frac{1}{K_{f/a}} + \frac{1}{K_{i/a}} \right)^{0.5}$ | |
| Pseudo-Activation | $K_{f/a} = a / \left( \left( \frac{K_m - K_0}{K_m} \right)^2 + \left( \frac{V^0 - V}{V} \right)^2 \right)^{0.5}$ | |
| $K_{i/a} = 1 / \left( \frac{1}{K_{f/a}} + \frac{1}{K_{i/a}} \right)^{0.5}$ | |
| Associative Activation | $K_{f/a} = a / \left( \left( \frac{K_m - K_0}{K_m} \right)^2 + \left( \frac{V - V^0}{V^0} \right)^2 \right)^{0.5}$ | |
| $K_{i/a} = 1 / \left( \frac{1}{K_{f/a}} + \frac{1}{K_{i/a}} \right)^{0.5}$ | |
| Competitive Activation | $K_{f/a} = a / \left( \left( \frac{K_m - K_0}{K_m} \right)^2 + \left( \frac{V^0 - V}{V^0} \right)^2 \right)^{0.5}$ | |
| $K_{i/a} = 1 / \left( \frac{1}{K_{f/a}} + \frac{1}{K_{i/a}} \right)^{0.5}$ | |
| Catalytic Activation | $K_{f/a} = a / \left( \left( \frac{K_m - K_0}{K_m} \right)^2 + \left( \frac{V - V^0}{V^0} \right)^2 \right)^{0.5}$ | |
| $K_{i/a} = 1 / \left( \frac{1}{K_{f/a}} + \frac{1}{K_{i/a}} \right)^{0.5}$ | |
| Unassociative Activation | $K_{f/a} = a / \left( \left( \frac{K_m - K_0}{K_m} \right)^2 + \left( \frac{V^0 - V}{V^0} \right)^2 \right)^{0.5} \left( \frac{1}{K_{f/a}} + \frac{1}{K_{i/a}} \right)^{0.5}$ | |
| $K_{i/a} = 1 / \left( \frac{1}{K_{f/a}} + \frac{1}{K_{i/a}} \right)^{0.5}$ | |
| Biparametrically Coordinated Activation | $K_{f/a} = a / \left( \left( \frac{K_m - K_0}{K_m} \right)^2 + \left( \frac{V - V^0}{V^0} \right)^2 \right)^{0.5}$ | |
| $K_{i/a} = 1 / \left( \frac{1}{K_{f/a}} + \frac{1}{K_{i/a}} \right)^{0.5}$ | |

Figure 1: Three dimensional (incompletely) system of rectangular coordinate with separately Pi and Pa semiaxes of molar concentrations of [i] inhibitor and [a] activator. Only 8 L vectors of enzymatic reactions (the symbols: L_1, L_2, L_3, L_4, L_5, L_6, L_7, L_8) are placed in appropriate parallelepipeds and four orthogonal projections of these L vectors (the symbols: L_1, L_2, L_3, and L_4) are placed on basic $\sigma_0$ plane (I, II, ... quadrants of this plane), the magnitude of $\Phi$ angle about 3400.

From Eq. (3) – the $l_{mi}$ length of the second adjacent of $l_{mi}$ vector projection on $PK_m$ semiaxis:

$$K_{i/a} = \frac{a}{\left( \left( \frac{K_m - K_0}{K_m} \right)^2 + \left( \frac{V - V^0}{V^0} \right)^2 \right)^{0.5}}$$

we shall obtain traditional form (t.f.) of equation for calculation of the $K_i$ constant of biparametrically coordinated, $I_i$ type, inhibition of enzymes, taking into consideration the $l_i$ length of orthogonal projection of $L_i$ vector on basic $\sigma_0$ plane of Figure (1a):

$$K_{i/a} = (i-0)(l_i) = \frac{1}{\left( \left( \frac{K_m - K_0}{K_m} \right)^2 + \left( \frac{V^0 - V}{V^0} \right)^2 \right)^{0.5}} \left( \frac{a}{l_{mi}} \right)$$

Where $l_i = \sqrt{(l_{mi})^2 + (l_{mi})^2}$, as it follows from Figures 1&2.
It is analogous for length of adjacent projections:

\[ l_{\text{III}} = l_{\text{IV}} = \sqrt{(l_{\text{III}})^2 + (l_{\text{IV}})^2}, l_{\text{I}} = \sqrt{(l_{\text{I}})^2 + (l_{\text{II}})^2}, l_{\text{II}} = \sqrt{(l_{\text{II}})^2 + (l_{\text{III}})^2}, l_{\text{I}} = \sqrt{(l_{\text{I}})^2 + (l_{\text{II}})^2}, l_{\text{III}} = \sqrt{(l_{\text{III}})^2 + (l_{\text{IV}})^2}, l_{\text{II}} = \sqrt{(l_{\text{II}})^2 + (l_{\text{III}})^2}, l_{\text{IV}} = \sqrt{(l_{\text{IV}})^2 + (l_{\text{III}})^2} \]

for all other \( l_{\text{III}} \), \( l_{\text{IV}} \) ... of vectors projections of biparametrical reactions (Figures 1,1a & 2).

**Figure 1a:** Three dimensional (completely) \( K_{\sigma}V \) coordinate system, (the same as Figure 1), but with all 14 branched L vectors (7 type of additional L vectors placed without appropriate arallelepips). The ends of all mobile L vectors are joined by dash line (broken part – activated, unbroken part– L vectors of inhibited reactions). The 15th \( L_0 \) vector of initial reaction (and its \( L_0 \) projection take place in P point of coordinate intersection. The all 14 orthogonal \( L_0 \), \( L_{\text{I}} \), \( L_{\text{II}} \) projections of L vectors on basic \( \sigma \) plane, are placed completely in (Figure 2). \( \sigma \) – first \( (l_{\sigma}) \) and \( \sigma_{\text{III-VI}} \) – third \( (\text{III-VI}) \) quadrants of transient \( \sigma \) plane, \( \sigma_{\text{III-VI}} \) and \( \sigma_{\text{VII-VIII}} \) – beginning and finishing ends of the line of orthogonal \( \sigma \) transient plane projection on basic \( \sigma \) plane (in Figures.1a and 2, market by broken lines), the magnitude of \( \phi \) angle about 3400.

**Figure 2:** Two-dimensional (scalar) \( K_{\sigma}V \) coordinate system. The symbols of kinetic parameters: \( K_{\sigma}, V, K_{\sigma} \) the projections \( L_{\text{III}}, L_{\text{IV}}, L_{\text{V}} \) of three-dimensional vectors: \( L_{\sigma}, L_{\text{III}}, L_{\text{IV}}, L_{\text{V}} \) on the basic \( \sigma \) plane and symbols of \( PK_{\sigma}, PO_{\sigma}, PO_{\sigma} \) and \( PV \) coordinate semiaxes the same as in Figure. 1 and in the text, the magnitude of \( \phi \) angle about 150.
Deduction of Quadratic form of Equations

From analysis of Equations (1-4) one can easily see that substitution in Eq. (4) of the dimensionless coordinates of the lengths of $L_{III}$ and $L_{IV}$ vector projections is equal to substitution in this equation of the $i/K_m$ and $i/K_{IV}$ parameters then it is not difficult to become the alternative equations for calculation of $K_i$ and $K_a$ constants of biparametrical types of inhibition and activation of enzymes. Having substituted in Eq. (4) of the dimensionless coordinates of the lengths of $L_{III}$ and $L_{IV}$ vector projections is equal to substitution in this equation of the $i/K_m$ and $i/K_{IV}$ parameters.

$$I_i = \sqrt{\left(\frac{i}{K_{III}}\right)^2 + \left(\frac{i}{K_{IV}}\right)^2}$$

we find that such as:

$$I_i = \frac{i}{K_{III}}$$

this substitution will lead to equation:

$$K_i = i/I_i = i/i_{III} = \left(1 + \frac{1}{K_{III}}\right)^{1/3} = 1 + \left(\frac{1}{K_{III}}\right)^{1/3}$$

or, in quadratic form:

$$\frac{K^2_i}{K_{III}} = \frac{1}{K_{III}} + \frac{1}{K_{IV}}$$

convenient for calculation of constant inhibition of enzymes (Eq. 1, q.f., in Table 1).

It is analogous for all the other equations of biparametrical types of inhibition (Eqs: 2, 5 – 7), and activation (Eqs: 9 – 11 and 14-15 of enzymes, Table 1q & 1f) such as orthogonal projections of correspond L vectors on the basic $\sigma$ plane, easy to determine by data of two-dimensional (scalar) $K_mV^*$ coordinate system (Figure 2), taking into account orthogonal L projections of tree-dimensional L vectors on basic $\sigma$ plane of (Figures 1a).

Examples of constants calculation.

**Example 1: Calculation of Constant Inhibition**

The inhibitory effect of Tungstic acid anions $WO_4^{2-} (0.5 \times 10^{-4} M)$ on the initial rate of pNPP cleavage by calf alkaline phosphatase (Figure 3).

shows that the presence $0.5 \times 10^{-4} M$ of these anions in the enzyme-substrate system makes the binding of the enzyme to the substrate cleaved ($K_{III}^0 = 4.45 \times 10^{-3} M, K_{IV}^0 = 6.56 \times 10^{-3} M$) difficult and leads to a decrease in the maximum reaction rate ($V_0 = 2.56, V = 1.74 \mu mol/ (min per \mu g protein)$). This meets all the features $(K_m^0 > K_m^0, V^* < V^0, i > 0)$ of the biparametrically coordinated, $I$, type, of enzyme inhibition (Table 1, line 1). Hence, to calculate the $K_I$ constant of this phosphatase inhibition it is necessary to use Eq. (5, text), or (Eq. 1, Table 1t & 1f).

Substitution in this equation of the parameters $K_m^0, K_m^0, V^*, V^0$ and $i$ obtained by data analysis of (Figure 3) allows the calculation of this constant of enzyme inhibition:

$$K_s = K_s = \frac{0.5 \times 10^{-4} M}{\left(\frac{6.56 - 4.45}{4.45}\right) + \left(\frac{2.56 - 1.74}{1.74}\right)} = 7.48 \times 10^{-4} M = 7.48 \times 10^{-4} M$$

**Figure 3**: Inhibitory effect of anions $WO_4^{2-}$ on the initial rate $V_0$, $\mu$ mol/ (min per $\mu$ g protein) of pNPP cleavage by calf alkaline phosphatase. Note: line 1 – the concentration of $WO_4^{2-}$ is $0.5 \times 10^{-4} M$; line (0) – the inhibitor is absent.
Substitution the same parameters (recalculated to values of $K_{im} = 1.602 \times 10^{-4} M$ and $K_{iv} = 1.055 \times 10^{-4} M$ constants) in equation (1 of Table 1t & 1f), result into next value of this $K_i$ constant:

$$K_i = K_a - \frac{0.5 \times 10^{-4} M}{0.669} = 0.747 \times 10^{-4} M - \frac{0.5 \times 10^{-4} M}{0.669} = 0.747 \times 10^{-4} M$$

(11)

Substitution of these parameters in (Eq. 1, q.f., Table 1)

$$\frac{1}{K_a} = \frac{1}{K_{im}} + \frac{1}{K_{iv}} = \frac{1}{K_{im}} + \frac{1}{K_{iv}} = \left( \frac{1}{1.055^2} + \frac{1}{1.055^2} \right)$$

(12)

result into the same value of the constant of enzyme inhibition:

$$K_i = \frac{1}{\sqrt{\frac{1}{K_{im}}}} = \frac{1}{\sqrt{0.7485 \times 10^{-4} M}} = \frac{1}{0.7485 \times 10^{-4} M} = 1.359 \times 10^{4} M$$

(13)

From Eqs. (10 -13) it follows that dimension of constants in all cases, are the molar concentration of inhibitor:

$$[M] = \frac{1}{K_i}$$

(14)

Control. Determine the value of the $K_{im}$ constant of this experiment (Figure 3) by values of $K_i$ and $K_{iv}$ constants.

From equations (11) and (12), rewritten to the form,

$$\left( \frac{1}{K_{im}} + \frac{1}{K_{iv}} \right) = \frac{1}{K_{im}} + \frac{1}{K_{iv}} = \left( \frac{1}{1.055^2} + \frac{1}{1.055^2} \right)$$

(15)

it follows that:

$$K_{im} = \frac{K_i^2 \cdot K_{iv}^2}{K_{im} \cdot K_{iv}} = 7.04 \times 10^{4} M$$

(18)

Substitution the necessary parameters from (Eq. 15) to (Eq. 16), we find that:

$$K_{im} = \left( \frac{0.748^2 - 1.055^2}{0.748^2} \right)^{10^{-4} M} = \left( \frac{0.5595 \times 1.113}{0.748^2} \right)^{10^{-4} M} = 1.125 \times 10^{-4} M = 1.061 \times 10^{-4} M$$

(17)

which is in good agreement with the experimental value of this constant (Eq. 12).

**Example 2: Calculation of Constant Inhibition**

The inhibitory effect of Pyrrolidine dithiocarbonic acid (PDTA) on the initial rate of pNPP cleavage by canine alkaline phosphatase shows that in the presence of $1 \times 10^{-5} M$ PDTA the parameters $K_{iv} = 4.69 \times 10^{-5} M$ and $V_0 = 2.921 \mu mol/(min per \mu g protein)$ change as follows $K_{iv} = 11.26 \times 10^{-5} M$ and $V = 3.616 \mu mol/(min per \mu g protein)$ (Figure 4). This corresponds to the, $V_i$ type, of enzyme pseudoinhibition ($K_{im} > K_{iv}, V > V_i, i > 0$) (Table 1, line 5) and Eq. (5, t.f.) is applicable for calculation of the $K_i$ constant of enzyme inhibition. Substitution all necessary parameters in this equation allows calculation of this constant of enzyme inhibition:

$$K_i = \frac{1 \times 10^{-4} M}{\left( \frac{11.26 - 4.69}{4.69} \right)^2 + \left( \frac{3.616 - 2.92}{2.92} \right)^2} = 7.04 \times 10^{4} M$$

(18)
Substitution of recalculated parameters of Figure 4, \( K_{iv} = 0.7138 \times 10^{-3} M \) and \( K_{iv} = 4.2029 \times 10^{-3} M \) to (Eq. 5, Table 1, q.f.) result into value of \( K_v \) constant inhibition:

\[
\frac{1}{K_v} = \frac{1}{K_{iv}} + \frac{1}{K_{iv}} = \left( \frac{1}{4.2029^2} + \frac{1}{0.7138^2} \right) = (2.0192)^{0.5} \times 10^{-4} M = (19)
\]

\[
K_v = \sqrt{1/2.0192} \approx 0.4951 = 7.036 \times 10^{-4} M
\]

**Example 3: Calculation of Constant Activation**

The activating effect of Guanosine (Guo) on canine alkaline phosphatase (Figure 5) shows that in the presence of \( 1 \times 10^{-3} M \) Guo the parameters of initial reaction of pNPP cleavage, i.e. \( k_a = 4.69 \times 10^{-3} M, V = 2.92 \mu\text{mol/(min per µg protein)} \), change as follows: \( K_{ai} = 5.67 \times 10^{-3} M, V = 3.527 \mu\text{mol/(min per µg protein)} \). This corresponds to the, I, type, of unassociative enzyme activation.

**Figure 5:** Activating effect of Guo on the initial rate \( v_0, \mu\text{mol/(min per µg protein)} \) of pNPP cleavage by canine alkaline phosphatase. Note: line 1 – the concentration of Guo is \( 31 \times 10^{-3} M \); line (0) - the activator is absent.

Hence, to calculate the \( K_{ia} \) constant of enzyme activation, one should use Eq. (14, t.f., Table 1).

Substitution of the obtained values of parameters in this equation allows calculation of this constant of enzyme activation:

\[
K_{ia} = 3.965 \times 10^{-3} M
\]  

(20)

Substitution of the: \( K_{iv} = 4.785 \times 10^{-3} M \) and \( K_{iv} = 4.819 \times 10^{-3} M \) parameters of this experiment (Figure 5) in (Eq. 14, q.f., Table 1), result in to:

\[
\frac{1}{K_{iv}^2} + \frac{1}{K_{iv}^2} = \frac{1}{23.223} + \frac{1}{23.766} = 0.0852 \times 10^3 M^{-1}
\]

(21)

As it was to be expected, result in to the same value of activation constant:

\[
K_{ia} = \frac{1}{\sqrt{0.0852 \times 10^3 M^2}} = \frac{1}{0.2919} \times 10^{-3} M = 3.426 \times 10^{-3} M
\]

(22)

From the length parts of equations: (12), (15), (19) and (21) may to see that all they obeys to the signs of Pitagor’s theorem and this may be used as for calculation any of the third constants by the two others known already and for correction the constants, determined by using any other equations.

**Example 4:** Calculate the value of \( K_{ia} \) constant of experiment (Figure 3), by value of \( K_{iv} \) and \( K_{iv} \) constants. From equation (1, Table 1t & 1f), rewritten to the quadratic form (23).

\[
\frac{1}{K_{ai}^2} + \frac{1}{K_{ai}^2} = \frac{1}{0.7485^2} + \frac{1}{K_{ai}^2} = \frac{1}{1.055^2}
\]

(23)

it follows that:

\[
K_{ai} = \left( \frac{K_{ai}^2 + K_{ai}^2}{K_{ai}^2 - K_{ai}^2} \right)^{0.5} M
\]

(24)

Having substitution all necessary parameters from (Eq. 23) to (Eq. 24), we shall become, that:

\[
K_{ai} = \frac{0.7485^2 \times 10^{-3} M}{0.7485^2 - 1.055^2} = 4.69 \times 10^{-3} M
\]

(25)

This is analogous for all biparametrically types of catalyzed reactions (Table 1).

Introduction in practice of quadratic forms of equations for calculation of \( K_i \) and \( K_a \) constants, will facilitates for many authors.
to interpret obtained data of nontrivial types of inhibition and activation by such definition as «essentially competitive inhibition», «similarly to competitive inhibition » and so on [13 -17].

References

1. Krupyanko VI (2004) A vector method of representation of enzymic reactions. Three-dimensional system of the coordinates convenient for representation of enzyme inhibition and activation. Process Biochem 39 (7): 825-832.
2. Krupyanko VI (2009) Perspectives of Data Analysis of Enzyme Inhibition and Activation. Part 1: Use of the Three-Dimensional Coordinate System for Data Analysis of Enzyme inhibition and Activation. J Biochem Mol Toxicol 23(2): 97-100.
3. Krupyanko VI (2009) Perspectives of Data Analysis of Enzyme Inhibition and Activation. Part 2: Parametrical Classification of Types of Enzymatic Reactions. J Biochem Mol Toxicol 23(2): 101-107.
4. Krupyanko VI (2009) Perspectives of Data Analysis of Enzyme Inhibition and Activation. Part 3: Equations for Calculation of the Initial Rates of Enzymatic Reactions. J Biochem Mol Toxicol 23(2): 108-118.
5. Krupyanko VI (2010) Perspectives of Data Analysis of Enzyme Inhibition and Activation. Part 4: Equations for Calculation of Constants of Enzyme Activation and Inhibition. J Biochem Mol Toxicol 23(2): 145-154.
6. Krupyanko VI (2014) Determination of intensity of enzyme inhibition and activation. Eur Chem Bull 3(6): 582-586.
7. Krupyanko VI (2014) Non-existence of secondary coordinates of intersects. Eur Chem Bull 3(8): 815-822.
8. Krupyanko VI (2015) Correction of Dixon Plots Eur Chem Bull 4(3): 142-153.
9. Krupyanko VI (2016) Correction of Data Analysis Equations Relating to Two-Substrate Enzyme Catalyzed Reactions. Eur Chem Bull 5(8): 354-363.
10. Webb L (1966) Inhibitors of Enzyme and Metabolism, [Russian translation], Mir, Moscow: pp: 6 - 862.
11. Segel IH (1975) Enzyme kinetics. J. Wiley, New York, pp: 1-957.
12. Dixon M, aWebb EC (1982) Enzymes (2) [Russian translation], Mir, Moscow, pp: 6-862.
13. Hovik R, Osmundsen (1989) HA kinetic investigation of the acyl-CoA oxidase reaction with the use of a novel spectrophotometric assay. Biochem J 263 (2): 297-299.
14. Bae-Lee M, Carman GM (1990) Regulation of yeast phosphatidylserine synthase and phosphatidylinositol synthase activiteas by phospholipids in triton X-100/phospholipid mixed micells. J Biol Chem 265 (13): 7221-7226.
15. Bakan DA, Saltman P, Theriault Y, Wright PE (1991) Kinetics and mechanisms of reduction of Cu(II) and Fe(III) complexes by soybean leghemoglobin a. Biochim Biophys Acta 1079(2): 182-196.
16. Hou B, Lim EK, Higgins GS, Bowles DJ (2004) N-Glucosylation of Cytokinins by Glycosyltransferases of Arabidopsis thaliana. J Biol Chem 279(46): 47822-47832.
17. Gibson LM, Lovelace LL, Leboda I (2008) The R163K Mutant of Human Thymidylate Synthase Is Stabilized on an Active Conformation, Structural Asymmetry and Reactivity of Cysteine 195. Biochemistry 47(16): 4636-4639.