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ALGEBRAIC DESCRIPTION OF TECHNICAL CHEMICAL SYSTEMS II.*

MATERIAL SYSTEMS AND CHANGES

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The material systems of technical chemistry, the changes occurring in these, their interpretation and their mathematical description are presented in this paper.

The qualitative description of the material systems was provided by determining

- the components present in the system,
- the relations between the components and
- the state of the system.

A quantitative description of the systems is presented by a matrix structure.

The technical chemical changes are characterized by the nature and type of the change and so it was possible to define the most important elementary changes.

Technical chemistry deals with material systems and with changes occurring in these [1] and the algebraic description of these will be given in the following.

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DESCRIPTION OF MATERIAL SYSTEMS

Qualitative Description

The starting point for the mathematical formulation of the systems is the following.

The material system is characterized by

- the components present in the system,
- the relations between the components, and
- the state of the system.

According to the above-mentioned characteristics, the material systems can be described by the following mathematical structure:

$$A = A\{\hat{K}, P, T\} \tag{1}$$

where

P - is the pressure,

T - is the temperature,

$\hat{K}$ - is the mathematical structure describing the components and the relations between these components.

The relation between the components may be

- homogenous, such as e.g. in the case of a mixture of liquids or a solution of a solid. The designation of the homogenous relation is the following: $\longrightarrow$
- heterogenous, such as e.g. a liquid dispersed in a gas or a humid solid. The designation of the heterogenous relation is the following: $\rightarrow$

The components can be characterized by the following structure:

$$K = K\{\alpha_{14}, \alpha_{15}, \alpha_{16}, \beta, \alpha_3, \alpha_4, \alpha_5\} \qquad (2)$$

where the first four elements designate a qualitative, whereas the others a quantitative property:

α_{14} - crystal structure,
α_{15} - chemical structure,
α_{16} - biological structure,
β - the state of the pure components of the material system pertaining to a pressure P and a temperature T. This may be

β_1 - solid
β_2 - liquid
β_3 - gaseous
β_4 - plasma

α_3 - scattering; the distribution of the component in the material system. The distribution may occur according to space co-ordinates or according to time.

The distribution according to space co-ordinates may be characterized by the scattering as used in the probability calculus:

$$\sigma^2 = \frac{\iiint\limits_v (c - \bar{c})^2 \, dv}{\iiint\limits_v dv} \qquad (3)$$

or with the entropy of mixing:

$$s_k = \frac{\iiint\limits_v c \ln c \, dv}{\bar{c} \ln \bar{c} \iiint\limits_v dv} \qquad (4)$$

where

c - is the concentration of the component,
$\bar{c}$ - is the mean concentration of the component,
v - is the volume of the system.

The fluctuation in time of the distribution of the component in a given point is

$$\sigma^2 = \frac{1}{t} \int_0^t (c - \bar{c})^2 \, dt \tag{5}$$

α^4 - is the characteristic dimension of the state of appearance of the component. Should this not exist, a "zero" is written in the algebraic structure (2) to the corresponding place. The dimension can be described e.g. by the equivalent sphere diameter, mass, volume, surface area, or also by the following expression:

$$\alpha_4^0 = \frac{n}{G} \tag{6}$$

where

n - is the number of entities in the component,
G - is the mass of the component.

α^5 - form. This can be given by the form factor (φ), by the ratio of characteristic dimensions, etc.

In accordance with Equation (2), a mass of spherical ($\varphi = 1$) γ-ferric oxide particles, 1 mm in diameter, can be described by the following structure:

$$K_{(\gamma \text{ ferric oxide})} = K\{\gamma,\ Fe_2O_3 \cdot 0,\ \beta_1,\ 0,\ 1,\ \varphi = 1\} \tag{7}$$

It is not always necessary to describe the components by the total mathematical structure. It is sufficient to describe only such elements as are of importance in the given individual case (e.g. which undergo some change in the process where the raw material is transformed to a final product).

If, for example, only the chemical structure of the component is of interest, we may write:

$$K = K\{Fe_2O_3\} \text{ ferric oxide}$$

or if only the state is of importance:

$$K = K\,\{\beta_1\} \text{ solid component}$$

When writing the expression for the components and the relations between them, the component determining the state of appearance of the system should be written in the first place. If the system is determined not by any one of the components but by their joint entity, the order in which the structure is written is of no consequence. In such a case, the designation of the homogenous relation is $\Longleftrightarrow$ and that of the heterogenous one is $\longleftrightarrow$.

A few examples for the homogenous relation between the components:

liquid mixture: $\hat{K} = K_1\,\{\beta_2\} \Longleftrightarrow K_2\,\{\beta_2\}$ (8)

solution of a solid: $\hat{K} = K_1\,\{\beta_2\} \Longrightarrow K_2\,\{\beta_1\}$ (9)

a solid dissolved in a liquid mixture: $\hat{K} = [K_1\{\beta_2\} \Longleftrightarrow K_2\{\beta_2\}] \Longrightarrow K_3\{\beta_1\}$ (10)

Examples for a heterogenous relation between the components:

humid solid:

$$\hat{K} = K_2\{\beta_1\} \longrightarrow K_1\{\beta_2\} \tag{11}$$

suspension:

$$\hat{K} = K_1\{\beta_2\} \longrightarrow K_2\{\beta_1\} \tag{12}$$

gas bubbles in a liquid:

$$\hat{K} = K_1\{\beta_2\} \longrightarrow K_2\{\beta_3\} \tag{13}$$

liquid droplets in a gas:

$$\hat{K} = K_2\{\beta_3\} \longrightarrow K_1\{\beta_2\} \tag{14}$$

liquid mixture dispersed in a gas:

$$\hat{K} = [K_1\{\beta_3\} \Longleftrightarrow K_2\{\beta_3\}] \rightarrow [K_3\{\beta_2\} \Longleftrightarrow K_4\{\beta_2\}] \tag{15}$$

The material systems which can be realized by relations between the components are summarized in Table [illegible]

Table 1

Nature of relation		Component 2. / Component 1. Determining	Solid β_1	Liquid β_2	Gaseous β_3
homogenous	⟹	solid β_1		liquid adsorbed at a solid phase	gas dissolved in or adsorbed at a solid phase
	⟺		homogenous solid-solid system; mixed crystal, alloy, glass		
	⟹	liquid β_2	solution of a solid		gas dissolved in a liquid
	⟺			liquid mixture	
	⟹	gas β_3	sublimated matter in a gas	liquid vapour in a gas	
	⟺				gas mixture
heterogenous	→	solid β_1	non-dispersed solid-solid system	liquid moving together with solid	gas moving together with solid
	↔		mixture of solids	thick slurry	non-dispersed heterogenous solid-gas system
	→	liquid β_2	suspension	emulsion	gas bubbles in a liquid
	↔		thick slurry	non-dispersed, immiscible liquid-liquid system	non-dispersed liquid-gas system
	→	gas β_3	flue dust in a gas	liquid droplets	
	↔		non-dispersed heterogenous solid-gas system	non-dispersed liquid-gas system	

Quantitative Description of Material Systems

The material systems can quantitatively be described by a matrix. The line vector (2) giving qualitative description is applied and resolved to two parts: one part describing the component

$$K' \; (\alpha_{14}, \; \alpha_{15}, \; \alpha_{16}, \; \beta) \qquad (16)$$

and the other describing the phase:

$$K'' \; (\beta', \; \alpha_3, \; \alpha_4, \; \alpha_5) \qquad (17)$$

In the case of more than one component and more than one phase, two matrixes are obtained. The component-matrix is the following:

$$\begin{bmatrix} (\alpha_{14})_1 & (\alpha_{14})_2 & \cdots \\ (\alpha_{15})_1 & (\alpha_{15})_2 & \cdots \\ (\alpha_{16})_1 & (\alpha_{16})_2 & \cdots \\ (\beta)_1 & (\beta)_2 & \cdots \end{bmatrix} \qquad (18)$$

and the phase-matrix:

$$\begin{bmatrix} (\beta')_1 & (\alpha_3)_1 & (\alpha_4)_1 & (\alpha_5)_1 \\ (\beta')_2 & (\alpha_3)_2 & (\alpha_4)_2 & (\alpha_5)_2 \\ \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot \end{bmatrix} \qquad (19)$$

A quantitative matrix containing as many lines as the number of the phases and as many columns as the number of the components in the system is obtained from the above mentioned two matrixes

$$\begin{array}{cc} & \begin{bmatrix} (\alpha_{14})_1 & \cdots \\ (\alpha_{15})_1 & \cdots \\ (\alpha_{16})_1 & \cdots \\ (\beta)_1 & \cdots \end{bmatrix} \\ \begin{bmatrix} (\beta')_1 & (\alpha_3)_1 & (\alpha_4)_1 & (\alpha_5)_1 \\ \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot \end{bmatrix} & \begin{bmatrix} x_{11} & x_{12} & \cdots \\ x_{21} & \cdots & \\ \cdot & \cdot & \\ \cdot & \cdot & \end{bmatrix} \end{array} \qquad (20).$$

where x is the weight fraction.

A further column vector, containing the information valid for the whole material system, is added to the matrix system.

$$\begin{bmatrix} \alpha_1, & t \\ \alpha_2, & y \\ \alpha_3 & \\ \alpha_7, & (T) \\ \alpha_8, & p \\ W & \\ \beta'' & \end{bmatrix} \qquad (21)$$

where

α_1 is time; t_o in the starting state, t_v in the final state, 0 in the case of a stationary system,

α_2 is place; y_o: input, y_v: exit; 0 if there is no change,

α_3 is the scattering of phase distribution,

α_7 is the temperature,

α_8 is the pressure,

W is the mass flux, if $\alpha_1 = 0$, or the mass of the system, if $\alpha_2 = 0$,

β' is the state of the phase,

β'' is the state of the material system.

For example, let us consider a material flux of a rate 15 kilograms per hour, T = 20°C, P = 1 atmosphere, containing uniformly dispersed NaCl particles of 1 millimetre size and of a form factor of 0.7 at a ratio of 0.2, suspended in a solution containing 60 per cent water, 20 per cent ethyl alcohol and 20 per cent NaCl solution. For this case we can write:

$$\begin{bmatrix} 0 & 0 & 0 \\ NaCl & H_2O & C_2H_5OH \\ 0 & 0 & 0 \\ \beta_1 & \beta_2 & \beta_2 \end{bmatrix}$$

$$\begin{bmatrix} 0 \\ y_o \\ 0 \\ 20 \\ 1 \\ 15 \\ \beta_2 \end{bmatrix} \quad \begin{bmatrix} \beta_2 & 0 & 0 & 0 \\ \beta_1 & 0 & 1 & 0{,}7 \end{bmatrix} \quad \begin{bmatrix} 0{,}16 & 0{,}48 & 0{,}16 \\ 0{,}2 & 0 & 0 \end{bmatrix}$$

Operations such as addition and subtraction can be carried out with the matrix systems. However, only matrix systems in which the phases and components are same and equal, can be added or subcontracted. Should this not be the case, the matrixes should be complemented. Prior to addition or subtraction the x-es are multiplied by W, the elements of the quantitative matrixes thus obtained are reduced and divided by $W_1 + W_2$. The elements of the qualitative matrixes remain unchanged and the reduction of the elements of the column vector is only indicated.

Various functions such as e.g. specific heat, can be interpreted by the matrix structure. In this case, a $C_{i,j}$ value pertains to every $X_{i,j}$ value, and if it is an additive property, the C value put into the column vector can be written in the following form:

$$C = \sum_{ij} x_{ij} \cdot C_{ij} \tag{22}$$

The qualitative mathematical structure can be supplemented by the property designated by C:

$$A\ \{K^{+}, P, T, C\} \tag{23}$$

where C represents in the above-mentioned example the specific heat of the material system. As already mentioned, only the relevant parameters are given in a number of cases; in the example this may be the specific heat only, and accordingly the short mathematical structure is the following:

$$A\ \{C\} \tag{24}$$

The quantitative description of material systems can also be performed in the following manner.

The component is described by a column vector

$$\begin{bmatrix} \alpha_{14} \\ \alpha_{15} \\ \alpha_{16} \end{bmatrix} \tag{25}$$

and the phase by a line vector

$$[\beta', \alpha_5, T, P, y, t] \tag{26}$$

(The designations are the same as used in the foregoing.)

In the description of <u>non-streaming material systems</u> the following quantitative parameters are given for all of the components of all of the phases:

g - mass
v - volume
n - numericality
s_k - entropy of mixing

The parameters are indexed according to the components (i) and phases (j), for example:

$$g_{i,j}$$

The following specific quantities are interpreted:

weight fraction:

$$c_{i,j} = \frac{g_{i,j}}{g_j} \tag{27}$$

volume fraction:

$$e_{i,j} = \frac{v_{i,j}}{v_j} \tag{28}$$

phase fraction:

$$\varepsilon_j = \frac{v_j}{\sum\limits_j v_j} \tag{29}$$

density:

$$\rho_{i,j} = \frac{g_{i,j}}{v_{i,j}} \tag{30}$$

mean mass:

$$\bar{g}_j = \frac{g_j}{n_j} \tag{31}$$

specific entropy of mixing:

$$s^{o}_{i,j} = \frac{s_{i,j}}{g_{i,j}} \tag{32}$$

In the description of streaming material systems the following quantitative parameters may be given:

W - mass flux

p - volume flux

m - numericality

ℓ - flux of entropy of mixing

In a way analogous to the foregoing, the following specific quantities are interpreted:

weight fraction:

$$c_{i,j} = \frac{w_{i,j}}{w_j} \tag{33}$$

volume fraction:

$$e_{i,j} = \frac{p_{i,j}}{p_j} \tag{34}$$

phase ratio:

$$\varepsilon_j = \frac{p_j}{\sum\limits_j p_j} \tag{35}$$

density:

$$\rho_{i,j} = \frac{w_{i,j}}{p_{i,j}} \tag{36}$$

mean mass:

$$\bar{g}_{i,j} = \frac{w_{i,j}}{m_{i,j}} \tag{37}$$

specific entropy of mixing:

$$s^{o}_{i,j} = \frac{\ell_{i,j}}{w_{i,j}} \tag{38}$$

The M_t quantitative matrix of a non-streaming material system:

$$\begin{bmatrix} (\alpha_{14})_1 & \cdots\cdots\cdots & (\alpha_{14})_i & \cdots \\ (\alpha_{15})_1 & \cdots\cdots\cdots & (\alpha_{15})_i & \cdots \\ (\alpha_{16})_1 & \cdots\cdots\cdots & (\alpha_{16})_i & \cdots \\ (\beta)_1 & \cdots\cdots\cdots & (\beta)_i & \cdots \end{bmatrix}$$

$$\begin{bmatrix} (\beta')_1, & (\alpha_5)_1, & T_1, & P_1, & t_1 \\ & & & & \\ (\beta')_j, & (\alpha_5)_j, & T_j, & P_j, & t_j \end{bmatrix} \begin{bmatrix} (g,v,n,s_k)_{1,\ell} & \cdots & (g,v,n,s_k)_{i,\ell} & \cdots \\ & & & \\ (g,v,n,s_k)_{1,j} & \cdots & (g,v,n,s_k)_{i,j} & \cdots \end{bmatrix} \tag{39}$$

The M_g quantitative matrix of a streaming material system:

$$\begin{bmatrix} (\alpha_{14})_1 & \cdots\cdots\cdots & (\alpha_{14})_i & \cdots \\ (\alpha_{15})_1 & \cdots\cdots\cdots & (\alpha_{15})_i & \cdots \\ (\alpha_{16})_1 & \cdots\cdots\cdots & (\alpha_{16})_i & \cdots \\ (\beta)_1 & \cdots\cdots\cdots & (\beta)_i & \cdots \end{bmatrix}$$

$$\begin{bmatrix} (\beta')_1, & (\alpha_5)_1, & T_1, & P_1, & y_1 \\ & & & & \\ (\beta')_j, & (\alpha_5)_j, & T_j, & P_j, & y_j \end{bmatrix} \begin{bmatrix} (w,p,m,\ell)_{1,\ell} & \cdots & (w,p,m,\ell)_{i,\ell} & \cdots \\ & & & \\ (w,p,m,\ell)_{1,j} & \cdots & (w,p,m,\ell)_{i,j} & \cdots \end{bmatrix} \tag{40}$$

The matrixes given in Equations (39) and (40) can, according to the experience, be more easily applied for the quantitative characterization of material systems, than the quantitative matrix described by Equation (20).

TECHNICAL CHEMICAL CHANGES

The changes can be considered as to

the nature of the change and
the type of the change.

The following designations are introduced:

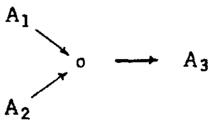
the characteristic is designated by α
the type of the change by v
the nature of the change by δ
the change by V
the various material fluxes are designated by "o",
the designation of "and" is $\wedge$
and that of "or" is $\vee$.

The nature of the change (δ)

- Linear change: δ_1

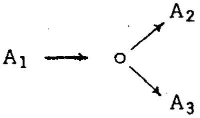
  in graphic representation: $A_1 \rightarrow o \rightarrow A_2$ i.e. material system A_1 is changed to material system A_2. Such changes are e.g. transportation or a change in temperature.

- Combining change: δ_2



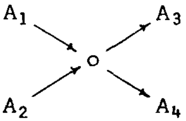
Two material systems are combined to give a third one; e.g. combination of two material streams, dissolution, chemical combination.

- Resolving change: δ_3



e.g. separation of two material streams, crystallization, chemical dissociation.

- Exchanging change: δ_4



This is the change of the most general nature in which two material streams are changed so as to yield two other material streams. For example, adsorption of a solute, mutual chemical exchange, etc.

From now on "the nature of the change" will be applied in generally sense. In written form an index (1-4) before the V will refer to the nature of the change.

The Types of the Changes

a) Change in the <u>place</u> (α_2): v_1

(The direction of the change is shown by the sign ±.)
The nature of the change may be $\delta_1 \vee \delta_2 \vee \delta_3$.

<u>Linear</u> change:

$$ {}_1V_1^{\pm} = v_1^{\pm} \wedge \delta_1 \tag{41}$$

Such is e.g. transportation.

<u>Combining</u> change:

$$ {}_2V_1 = v_1 \wedge \delta_2 \tag{42}$$

E.g. combination of two totally miscible streams.

Resolving change:

$$_3V_1 = v_1 \wedge \delta_3 \tag{43}$$

E.g. resolution of a stream into partial streams of identical properties.

b) Change in the scattering (α_3): v_2

A change according to the place or time co-ordinates in the distribution of any of the characteristics is representated by the change in scattering. Increasing scattering is given a positive sign, decreasing scattering a negative sign.

The nature of the change may be: δ_1

$$_1V_2^{\pm} = v_2^{\pm} \wedge \delta_1 \tag{44}$$

E.g. pressure-equalizer buffer vessel.

c) Change in the dimensions (α_4): v_3

The nature of the change may be: $\delta_1 \vee \delta_2 \vee \delta_3$.

Linear change:

$$_1V_3 = v_3 \wedge \delta_1 \tag{45}$$

E.g. increasing or decreasing of dimensions.

Combining change:

$$_2V_3 = v_3 \wedge \delta_2 \tag{46}$$

E.g. supplying a dimensionless body with dimension (freezing).

Resolving change:

$$_3V_3 = v_3 \wedge \delta_3$$

E.g. abolishment of dimensions (sublimation).

d) Change in the form (α_5): v_4

The nature of the change may be: $\delta_1 \vee \delta_2 \vee \delta_3$.

Linear change may be the change in the form of the material system along a favoured direction (±).

$$ {}_1V_4^{\pm} = v_4^{\pm} \wedge \delta_1 \tag{48} $$

Combining change may be supplying a formless system with form:

$$ {}_2V_4 = v_4 \wedge \delta_2 \tag{49} $$

Resolving change may e.g. be the abolishment of form (melting):

$$ {}_3V_4 = v_4 \wedge \delta_3 \tag{50} $$

e) Change in the temperature (α_6): v_5

The nature of the change may be: $\delta_1 \vee \delta_2 \vee \delta_3$. The change in the temperature may be brought about by processes occurring in the material system (e.g. evaporation, consideration) or by an exchange of energy.

Linear change: change in temperature without external energy exchange:

$$ {}_1V_5^{\pm} = v_5^{\pm} \wedge \delta_1 \tag{51} $$

E.g. heat exchange.

Combining change: the temperature increases by the introduction of external energy:

$$ {}_2V_5 = v_5 \wedge \delta_2 \tag{52} $$

Resolving change: the temperature decreases in consequence of heat extraction:

$$ {}_3V_5 = v_5 \wedge \delta_3 \tag{53} $$

E.g. expansion-type refrigerators.

f) Change in the pressure (α_7): v_6

The nature of the change may be: $\delta_1 \vee \delta_2 \vee \delta_3$.

The change is a linear one, if the change in pressure occurs without the action of external energy:

$$ {}_1V_6^{\pm} = v_6^{\pm} \wedge \delta_1 \tag{54} $$

such as boiling or condensation.

The change is combining, if the pressure is increased by the action of external energy:

$$ {}_2V_6 = v_6 \wedge \delta_2 \tag{55} $$

e.g. compression.

The change is resolving, if the pressure is decreased by the action of external energy:

$$ {}_3V_6 = v_6 \wedge \delta_3 \tag{56} $$

e.g. expansion.

g) Change in the state (α_8): v_7

The nature of the change may be only linear. The direction of the change may be positive:

$$ {}_1V_7^{\pm} = v_7^{+1} \wedge \delta_1 \tag{57} $$

e.g. a liquid is produced from a solid. Or it may be negative:

$$ {}_1V_7{}^{1} = v_7^{-1} \wedge \delta_1 \tag{58} $$

e.g. a solid is produced from a liquid. Equations (57) and (58) describe one-step changes in state.

In general form:

$$ A_{yo}[\beta_a] + {}_1V_7^{+1} = A_{yv}[\beta_{a+1}] \tag{59} $$

$$ a = 1,\ 2 $$

where A_{yo} = initial,
A_{yv} = final material system

$$A_{yo}[\beta_a] + {}_1V_7^{-1} = A_{yv}[\beta_{a-1}] \qquad (60)$$

$$a = 2,3$$

Two-step changes in state

A gas is produced from a solid:

$$A_{yo}[\beta_1] + {}_1V_7^{+2} = A_{yv}[\beta_3] \qquad (61)$$

A solid is produced from a gas:

$$A_{yo}[\beta_3] + {}_1v_7^{-2} = A_{yv}[\beta_1] \qquad (62)$$

h) Change in the phase ratio (α_9): v_8

The nature of the change: $\delta_2 \vee \delta_3 \vee \delta_4$.

Combining change: a heterogenous system is produced from separate material streams, or - with different wording - material streams are united to a heterogenous system:

$$ {}_2V_8 = v_8 \wedge \delta_2 \qquad (63)$$

$$A_{yo,1} \circ A_{yo,2} + {}_2V_8 = A_{yv,1} \rightarrow A_{yv,2} \qquad (64)$$

e.g. preparation of a suspension.

Resolving change is, naturally, the resolution of a heterogenous system

$$ {}_3V_8 = v_8 \wedge \delta_3 \qquad (65)$$

$$A_{yo,1} \rightarrow A_{yo,2} + {}_3V_8 = A_{yv,1} \circ A_{yv,2} \qquad (66)$$

e.g. filtration of a suspension.

Exchanging changes place the heterogenous connection to between other phases.

$$ {}_4V_8 = v_8 \wedge \delta_4 \qquad (67)$$

$$A_{yo,1}[\beta_a \rightarrow \beta_b] \circ A_{yo,2}[\beta_o] + {}_4V_8 =$$

$$= A_{yv,1}[\beta_a] \circ A_{yv,2}[\beta_c \rightarrow \beta_b] \qquad (68)$$

e.g. humid dust separation.

i) Change in the ratio of components within the phase (α_{10}): v_9

The nature of the change is: $\delta_2 \vee \delta_3 \vee \delta_4$.

The change is combining, if heterogenous phases are united to give a homogeneous system:

$${}_2V_9 = v_9 \wedge \delta_2 \qquad (69)$$

$$A_{yo}[\beta_a \rightarrow \beta_b] + {}_2V_9 = A_{yv}[\beta_a \Longrightarrow \beta_b] \qquad (70)$$

The change may be regarded of resolving nature, if a homogenous system is resolved into a heterogenous one:

$${}_3V_9 = v_9 \wedge \delta_3 \qquad (71)$$

$$A_{yo}[\beta_a \Longrightarrow \beta_b] + {}_3V_9 = A_{yv}[\beta_y \rightarrow \beta_b] \qquad (72)$$

e.g. crystallization by cooling.

Exchanging changes occur with transportation of the homogenous relation:

$${}_4V_9 = v_9 \wedge \delta_4 \qquad (73)$$

$$A_{yo}[(\beta_a \Longrightarrow \beta_b) \rightarrow \beta_c] + {}_4V_9 =$$

$$= A_{yv}[(\beta_a \Longrightarrow \beta_c) \rightarrow \beta_b] \qquad (74)$$

e.g. crystallization by salting out.

j) Change in the crystal structure (α_{14}): v_{10}

The nature of the change may be: $\delta_1 \vee \delta_2 \vee \delta_3$.

Linear change is a change in crystal modification; e.g. α-iron is transformed to γ-iron.

$${}_1V_{10} = v_{10} \wedge \delta_1 \tag{75}$$

$$A_{yo}[(\alpha_{14})_1] + {}_1V_{10} = A_{yv}[(\alpha_{14})_2] \tag{76}$$

Combining change is the production of a crystal structure, e.g. in a crystallization process.

$${}_2V_{10} = v_{10} \wedge \delta_2 \tag{77}$$

Resolving change is the abolishment of crystal structure, e.g. melting.

$${}_3V_{10} = v_{10} \wedge \delta_3 \tag{78}$$

k) Change in chemical structure (α_{15}) and in the distribution of chemical elements among the components (α_{11}): v_{11}

The nature of the change: $\delta_1 \vee \delta_2 \vee \delta_3 \vee \delta_4$

In a linear change no matter is added to the component and none is removed from it, e.g. izomerization.

$${}_1V_{11} = v_{11} \wedge \delta_1 \tag{79}$$

$$A_{yo}[(\alpha_{15})_1] + {}_1V_{11} = A_{yv}[(\alpha_{15})_2] \tag{80}$$

In chemical combination:

$${}_2V_{11} = v_{11} \wedge \delta_2 \tag{81}$$

$$A_{yo,1}[(\alpha_{15})_1] \circ A_{yo,2}[(\alpha_{15})_2] + {}_2V_{11} = \\ = A_{yv}[(\alpha_{15})_3] \tag{82}$$

In chemical decomposition:

$${}_3V_{11} = v_{11} \wedge \delta_3 \tag{83}$$

$$A_{yo}[(\alpha_{15})_1] + {}_3V_{11} = \\ = A_{yv,1}[(\alpha_{15})_2] \circ A_{yv,2}[(\alpha_{15})_3] \tag{84}$$

In chemical exchange:

$$_4V_{11} = v_{11} \wedge \delta_4 \tag{85}$$

$$A_{yo,1}[(\alpha_{15})_1] \circ A_{yo,2}[(\alpha_{15})_2] + {}_4V_{11} =$$

$$= A_{yv,1}[(\alpha_{15})_3] \circ A_{yv,2}[(\alpha_{15})_4] \tag{86}$$

1) Change in the biological characteristics: v_2

where the distribution of compounds among the biological systems (α_{12}), the density of the biological individual (α_{13}) and the biological structure (α_{16}) are regarded as characteristic figures.

The nature of the change may be: $\delta_1 \vee \delta_2 \vee \delta_3$.

Linear change is the change of the biological structure.

$$_1V_{12} = v_{12} \wedge \delta_1 \tag{87}$$

$$A_{yo}[(\alpha_{16})_1] + {}_1V_{12} = A_{yv}[(\alpha_{16})_2] \tag{88}$$

Combining change: growth of the biological individuals.

$$_2V_{12} = v_{12} \wedge \delta_2 \tag{89}$$

$$A_{yo}[(\alpha_{12})_1] + {}_2V_{12} = A_{yv}[(\alpha_{12})_2] \tag{90}$$

Resolving change: reproduction of the individuals, which brings about an increase in the density of the individuals.

$$_3V_{12} = \overset{+}{v}_{12} \wedge \delta_3 \tag{91}$$

$$A_{yo}[(\alpha_{13})_1] + {}_3V_{12} = A_{yv}[(\alpha_{13})_2] \tag{92}$$

Death of the individual means a decrease in the number of the individuals

$$_3V_{12}^{-1} = v_{12}^{-1} \wedge \delta_3 \tag{93}$$

$$A_{yo}[(\alpha_{13})_1] + {}_3V_{12}^{-1} = A_{yv}[(\alpha_{13})_2] \tag{94}$$

or:

$$A_{yo}[(\alpha_{16})_1] + {}_3V_{12}^{-1} = A_{yv}[(0)] \tag{95}$$

Equations (31) to (95) interpret elementary changes. A change is called elementary if only one of the characteristics is changed, even if such a change would lead to a fictive material system (e.g. a material possessing a crystal structure, but, at the same time, without any chemical structure). Consequently, a part of the elementary changes is impossible in itself alone. On the other hand, elementary changes as defined in the foregoing permit all possible real changes to be synthetized.

REFERENCE

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РЕЗЮМЕ

Авторы в данном сообщении занимаются материальными системами технической химии, и изменениями происходящими по ним, далее излагают их толкование и математическое описание.

Начественное описание материальных систем было выполнено определением

- компонентов, находящихся в системе,
- взаимных связей между компонентами, и
- состояния системы.

Материальные системы количественно определены матрицным выражением.

Технико-химические изменения были характеризованы видом и типом изменения, таким способом можно было отметить наиболее важные элементарные изменения.

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STUDIES ON THE HYDRODINAMICS OF FLUIDIZED LAYERS II. STREAMING OF FLUID, PARTICLE MOTION AND LAYER EXPANSION IN SYSTEMS FLUIDIZED WITH A LIQUID

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Starting from the physical model, basic equations are derived for the flow of the fluid, particle motion and changes in particle density along the radius. These equations enable the fluid-mechanical properties of fluidized systems to be described.

The basic equations derived are applied to systems fluidized with a liquid, and equations are presented for the calculation of the inter-granular liquid flow rate, of the change in grain flow rate along the radius and of the void fraction.

INTRODUCTION

Various theories have been described in literature for the description of the fluid mechanical properties, such as expansion and viscosity of the layer, and the motion of particles, etc., in fluidized layers [1, 2, 3, 4, 5, 6] etc. Based on these theories a number of equations was derived; however, the practical application of these is cumbersome and difficult.

In the following, based on a physical model, the derivation of equations enabling the calculation of the most important fluid