VOL. XXXIV. JANUARY, 1912. No. 1.

THE JOURNAL

OF THE

American Chemical Society

A PROPOSED SYSTEM OF NOTATION FOR PHYSICO-CHEMICAL QUANTITIES.

BY ARTHUR A. NOYES.

Received December 2, 1911.

In spite of the considerable amount of attention which the matter has received, no system of notation for physico-chemical quantities has yet been devised of a character sufficiently satisfactory to secure its general adoption. The fact that the matter is to be considered by the new International Association of Chemical Societies leads the writer to present in this paper the outlines of a system of notation which has been worked out gradually through a series of years, in connection with the publications and lecture work of this laboratory. The development of the system was also greatly aided by the consideration given to the matter some years ago by a committee of representatives of various American scientific societies. It is presented here not as a final plan, but with the hope that it may be useful as a basis of further discussion.

In the writer's opinion the problem has usually been attacked on the wrong side. Instead of first formulating certain fundamental principles upon which a system might be consistently constructed, the specific task has been undertaken at once of assigning symbols to the large number of separate quantities. There is, moreover, at best, great difficulty in securing a fair compromise between the development of a rational, consistent system, and the retention of such specific symbols as are in general use. As a rule, adequate systematization seems to the writer to have been too greatly subordinated to the desire to retain familiar symbols. On the other hand, in some of the systematic plans proposed by individuals too little effort has been devoted to reconciling the notation with that in general use.

The following principles are suggested as the basis of the system of notation:

1. Quantities should be expressed by such symbols as can be conveniently used and readily distinguished, both in printing and writing. The symbols should also be such as can be described by short simple names.

2. Four distinct alphabets (styles of letters) are necessary and sufficient for a satisfactory system of notation of physico-chemical quantities.[1] If only three alphabets are employed, the same symbol has too often to be used to represent distinct quantities; or else, in order to avoid this, letters which are not in common use have to be used for many quantities.

3. The alphabets that can be best employed seem to be:
   1. Italic small letters (*a*, *b*, *c*).
   2. Italic capitals (*A*, *B*, *C*).
   3. Black-face Roman capitals (**A, B, C**).
   4. Greek letters (both small letters and capitals).

The main objection to the black-face Roman capitals seems to be that they are too prominent in comparison with the other letters. This objection is to be weighed against the advantage of the great simplicity of the Roman letters. It is especially desirable to use a style which printers are accustomed to use in ordinary composition. Other styles that might be used are ordinary Roman capitals (A, B, C), black-face small letters (**a, b, c**), Roman small capitals (A, B, C), or italic small capitals (*A*, *B*, *C*). What is essential, in the writer's opinion, is that some fourth alphabet be consistently employed for a certain group of quantities. The following expression of the Helmholtz equation illustrates the use of three of the styles in a single formula:

$$T\frac{d\mathbf{E}}{dT} = \frac{Q}{\mathbf{F}} - \mathbf{E}.$$

4. The letters of any one alphabet should, in general, be used only for quantities related to certain specified divisions of science.

5. Fundamental geometrical and mechanical quantities should be represented by italic small letters; energetic, thermal and chemical quantities, by italic capitals; electrical quantities by black-face Roman capitals; optical quantities by Greek small letters; special mathematical or mechanical quantities by Greek capitals or small letters. Abbreviations of the names of mathematical functions (such as log, sin) should be represented by Roman small letters. In manuscript the style of letter is to be indicated by the usual conventional signs—italics by underlining with a straight line, black-face by underlining with a curved line. In blackboard work and other similar writing, the italic small letters and capitals

[1] In physics, where magnetic quantities are also to be dealt with, a fifth alphabet would be desirable for these.

are to be represented by script letters, the black-face capitals by printed Roman letters.

6. The attempt should not be made to indicate the units in which quantities are expressed by the use of different symbols.

7. Different values of the same kind of quantity should be indicated by numerical or literal subscripts or by accents.

8. The specific value of any quantity (that is, the value of it when the other determining factors have the value unity) may be represented by overlining the symbol representing the quantity in general. Thus, if v is volume, $\bar{v}$ is specific volume; if R is resistance, $\bar{\mathrm{R}}$ is specific resistance. The overline may be omitted when no misunderstanding is likely to result.

9. The same symbol is not to be used for different quantities which are likely to occur in the same expression, but may be so used, if necessary, where the quantities rarely occur together (especially if none of them are very common or fundamental ones).

10. A letter that is almost universally employed in all languages to denote a certain quantity should be adopted for that quantity, but (except in case of Greek letters) it should be in the alphabet corresponding to the nature of the quantity, as defined in paragraph 5.

11. In the choice of other symbols the primary consideration should be the development of a consistent, non-conflicting system of notation. A secondary consideration should be to secure conformity with the international usage. In case following the most common usage would introduce serious complications into the system, or in the case of conflicting usage, a symbol not in common use may be employed; but in such cases a symbol suggesting the Latin form of the name of the quantity, or if this is not practicable, its Teutonic form is to be preferred.

12. In a system of notation proposed for general acceptance only those quantities should be included which are fairly fundamental in character or are of frequent occurrence.

The following table shows a system of notation developed in accordance with these principles:

SYSTEM OF NOTATION OF PHYSICO-CHEMICAL QUANTITIES.

GEOMETRICAL AND MECHANICAL QUANTITIES.

a area; acceleration; van der Waals' constant; activity.[1]

b van der Waals' constant.

c concentration.[2]

d differential; density.

e base of natural logarithms.

f force.

g acceleration by gravity.

[1] Defined by the equation $dF = RTd \log a$.

[2] In formula weights or moles per unit-volume unless otherwise stated. For concentration in equivalents per unit-volume, the symbol **C** or C is proposed.

h height.
i moles from one formula weight or the van't Hoff coefficient;[1] square-root of minus one ($\sqrt{-1}$).
j —.
k constant.
l length; distance.
m mass or weight (as quantity of matter).
n number (of terms, revolutions, etc.); number of molecules.
o —.
p pressure.
q —.
r radius.
s solubility.[2]
t time; temperature centigrade.[3]
u velocity.
v volume.
w weight (as force).
x y z coördinates, variables, unknowns.
x mol-fraction.

ENERGETIC, THERMAL AND CHEMICAL QUANTITIES.

A atomic weight; work-producing power.[4]
B constant.
C heat capacity.
D —.
E energy in general.
F free energy.[5]
G —.
H internal-energy function.[6]
I —.
J mechanical equivalent of heat.
K equilibrium-constant.
L latent heat (of vaporization, solution, fusion).
M molecular weight.
N number of formula-weights or mols.[7]
O —.
P power.
Q heat absorbed.
R gas-constant.
S entropy.
T absolute temperature.
U internal energy.
V —.
W work.
X Y Z coördinate axes.

ELECTRICAL QUANTITIES.

A —.
B —.
C electrical capacity; concentration in equivalents per unit volume.
D density (of charge or current).
E electromotive force.
F faraday.
G —.
H —.
I current strength.
J —.
K dielectric constant.
L conductance.
M —.
N number of faradays; number of equivalents.
O —.
P —.
Q quantity of electricity.
R resistance.
S —.
T transference number.
U mobility of ions.
V potential.
W —.
X Y Z —

[1] Defined by the equation $\Pi = icRT$.

[2] In formula weights or moles per unit-volume unless otherwise stated.

[3] In cases where confusion between time and centigrade temperature might result the latter mey be represented by θ or by T.

[4] Measured by the work produced when the change in question takes place reversibly.

[5] Defined by the equation $F = A + \Sigma(pv)$.

[6] Defined by the equation $H = U + \Sigma(pv)$.

[7] For "number of equivalents" the symbol **N** or N is proposed.

OPTICAL AND SPECIAL QUANTITIES.

α angle of optical rotation; empirical coefficient.
β empirical coefficient.
γ degree of ionization.
Γ —.
δ variation sign, residual.
ϑ partial differential.
Δ increment.
ϵ —.
ζ —.
η viscosity; efficiency.
θ angle.
Θ —.
ι intensity of light.
κ heat-capacity ratio (C_p/C_v).
λ wave length; mean free path.
Λ equivalent conductance.
μ micron; magnetic permeability.
ν refractive index.
ξ —.
Ξ —.
π ratio of circumference to diameter.
Π osmotic pressure.
ρ refractive power.
σ surface tension.
Σ summation sign.
τ —.
υ velocity of light.
Υ —.
φ angle; fluidity.
Φ —.
X ψ —.
Φ Ψ —.
ω angular velocity.
Ω —.

Attention may be called to two or three important inconsistencies or defects in the above system. Time and centigrade temperature are both represented by the same symbol t. This is proposed for the reason that it is desirable to represent these two fundamental, very commonly occurring quantities by simple suggestive symbols such as are in common use, and for the reason that the confusion arising from the use of the same symbol for these two quantities is not very serious, since they seldom occur together. Density and the differentiation sign are also represented by the same symbol d, which again is not very serious, since they seldom occur together. Number of equivalents **N** and equivalent concentration **C** are represented by a style of type which is otherwise used only for electrical quantities; for this there is, however, a certain logical justification, since in electrochemical considerations equivalents are often involved. These inconsistencies can be removed by representing these quantities by letters of a special style, preferably by italic or Roman small capitals, thus representing centigrade temperature by *T*, density by *D*, number of equivalents by *N*, and concentration in equivalents per unit-volume by *C*. The writer is inclined to favor making these symbols optional.

Some additional specifications which it seems desirable to make are as follows:

1. Partial values of a quantity of any kind are to be indicated by appropriate subscripts, not by distinct symbols. For example, partial pressures by p_1, p_2, p_{H_2}, p_{CO_2}..; partial volumes by v_1, v_2..; separate potentials by $\mathbf{E}_{Ag}$, $\mathbf{E}_{Cl}$..; ion mobilities and conductances by $\mathbf{U}_{K^+}$, $\mathbf{U}_{Cl^-}$, Λ_{K^+}, Λ_{Cl^-}.

2. The molal values of various quantities would be represented under the proposed system by such symbols as $M\bar{v}$, $M\bar{C}$, $M\bar{\mathbf{L}}$. It may be desirable to introduce some sign to indicate the molal value. Overlining with a curved line or with two straight lines is suggested; for example, $\overset{\frown}{v}$, $\overset{\frown}{C}$, $\overset{\frown}{\mathbf{L}}$ or $\bar{\bar{v}}$, $\bar{\bar{C}}$, $\bar{\bar{\mathbf{L}}}$.

3. Critical and reduced quantities are to be indicated by the subscripts C and R, not by special symbols; for example, T_C, T_R, v_C, v_R, p_C, p_R.

4. Ions and the sign and magnitude of their charges are to be indicated by very small plus and minus signs attached to the chemical symbols as superiors, not written in the line above it. For example, K^+, Ba^{++}, Cl^-, SO_4^{--}.

5. In mass-action expressions concentrations may be expressed by enclosing the chemical symbols within parentheses; for example, $(H_2)\,(I_2) = K(HI)^2$.

6. In expressions of the properties of dilute solutions, quantities pertaining to the solvent (or zero concentration of the solute) are to be indicated by the subscript zero; quantities pertaining to the solute or solution by letters without subscripts (or by numerical subscripts 1, 2..).

The following equations illustrate the expression of a few of the more important physico-chemical relations by the above system of notation:

$$pv = NRT = {}^1/_3 nMu^2.$$

$$n/N = \text{the "Avogadro constant."}$$

$$\frac{C_p}{C_v} = \frac{5}{3}\,\frac{\Delta E_K}{\Delta E}.$$

$$\frac{p_0 - p}{p_0} = \frac{N}{N + N_0} = x;\ \text{or}\ p = p_0\,\frac{N_0}{N + N_0} = x_0 p_0.$$

$$\Pi = RT\,\frac{d_0}{M_0}\,\log\frac{p_0}{p}.$$

$$\mathbf{L} = 1/\mathbf{R} = \mathbf{I}/\mathbf{E};\ \mathbf{L} = \bar{\mathbf{L}}a/l.$$

$$\mathbf{E}_M = \bar{\bar{\mathbf{E}}}_M - \frac{RT}{\mathbf{NF}}\log C_{M^+}.$$

$$M\rho = \frac{M}{d}\,\frac{\nu^2 - 1}{\nu^2 + 2};\ \nu = \frac{\sin\varphi_1}{\sin\varphi_2} = \frac{\nu_1}{\nu_2}.$$

RESEARCH LABORATORY OF PHYSICAL CHEMISTRY.
MASS. INSTITUTE OF TECHNOLOGY,
BOSTON, December, 1911.