ACTA CHEMICA SCANDINAVICA **11** (1957) 382—390

Recommendations by the Commission on Physico-Chemical Symbols and Terminology under the International Union of Pure and Applied Chemistry (IUPAC), 1955

The following pages contain a reprinted edition of the recommendations by the above mentioned Commission from its meeting in Zürich 1955. It has been submitted to this journal by its chairman J. A. Christiansen, who has also read the proofs.

RECOMMENDATIONS ON MATTERS OF DETAIL

The recommendations on the following pages are mainly those agreed upon in Amsterdam (1949), with modifications which subsequent discussions in the commission have made desirable. The commission refers to the report of 1949 concerning the history and concerning the agreement with recommendations from related bodies, especially the S. U. N. commission of I. U. P. A. P.

Referring to section III below the commission has found it desirable however to quote two paragraphs from the introduction to the report of 1949.

"It is recognised that recommendations by an international body must involve compromises and will sometimes have to include alternative usages for particular quantities from which the various national organisations can select those most closely in accord with their established practices. The proposals now made are not therefore intended to prescribe rigidly usages that should be universally adopted, but to give guidance in seeking a wider measure of international agreement and warning of instances where existing diversities may cause misunderstandings."

"Even among chemists in different countries, or belonging to different schools, complete agreement has not been attained on the use of symbols for certain quantities and in a few instances it may be necessary, at least temporarily, to agree to disagree and to say so."

I. NUMBERS AND MATHEMATICAL OPERATIONS

Numbers should be printed in upright figures, using a comma or point only to separate whole numbers from the decimals. To facilitate reading of long numbers the figures may be grouped together in threes without using commas or points to separate the groups.

Symbols for mathematical operations should be printed in roman (upright) type.

II. ABBREVIATIONS FOR WORDS

To be printed in upright type.

A. ABBREVIATIONS FOR THE NAMES OF UNITS

Abbreviations for units named after persons begin with a capital letter. Single capital letters used as abbreviations may be printed in smaller type than is used in the body of the text, but practice in this varies and no recommendation is made.

metre	m	degree Celsius (1)	°C
micron	μ	degree Fahrenheit (1)	°F
ångström	Å	degree Kelvin (1)	°K
litre	l	lumen	lm
second	s	lux	lx
minute	min	stilb	sb
hour	h	candela	cd
hertz	Hz	coulomb	C
gramme	g	ampère	A
tonne	t	volt	V
dyne	dyn	ohm	Ω
newton	N	farad	F
bar	b	henry	H
poise	P	molal (concentration) (2)	m
joule	J	molar (concentration) (2)	M
watt	W	normal (concentration) (2)	N
calorie	cal	formal (concentration) (2)	F

Prefixes to abbreviations for the names of units indicating:

Multiples			Sub-multiples		
tera	10^{12}	T	deci	10^{-1}	d
giga	10^{9}	G	centi	10^{-2}	c
mega	10^{6}	M	milli	10^{-3}	m
kilo	10^{3}	k	micro	10^{-6}	μ
			nano	10^{-9}	n
			pico	10^{-12}	p

(1) The °sign and the letter following form *one symbol* and there should be no space between them *e. g.* 25 °C or 25°C but *not* 25° C.

(2) Used only when preceded by numerals to indicate the magnitude of a concentration in the specified terms and not as symbols for concentrations in equations.

B. ABBREVIATIONS FOR OTHER WORDS

These will vary with the language used and no attempt is therefore made to secure uniformity of practice at an international level.

A full point is sometimes used after abbreviations but this practice is not recommended except when required to avoid confusion.

III. SYMBOLS FOR PHYSICAL AND CHEMICAL QUANTITIES

Symbols for physical and chemical quantities, in contrast to abbreviations for units, should be printed in sloping (italic) type whenever these symbols are letters of the latin alphabet and if practicable when they are letters of the greek alphabet. A bold face italic type may be used to represent certain specified physical constants or conversion factors.

Symbols separated by commas represent equivalent recommendations.

Symbols preceded by three dots are alternatives to be used only when there is some reason for not using a symbol before the three dots.

Space, time, mass and related quantities

	Quantity	Symbol
1	length	l
2	height	h
3	radius	r
4	diameter	d
5	path, length of arc	s
6	plane angle	$\alpha, \beta, \gamma, \vartheta, \varphi, \psi$
7	solid angle	ω
8	area	A, S
9	volume	$V \ldots v$
10	specific volume	v
11	wave length	λ
12	wave number	σ, ν
13	time	t
14	period or other characteristic time interval	T, τ
15	frequency	ν, f
16	angular frequency ($2 \pi \nu$)	ω
17	velocity	$v \ldots u, w$
18	angular velocity	ω
19	acceleration	a
20	» of free fall	g
21	mass	m
22	moment of inertia	I
23	density	ϱ
24	relative density	d

Molecular and related quantities

	Quantity	Symbol
101	molecular mass	m
102	molar mass	M
103	Avogadro's number	N_0, L, N
104	number of molecules	N
105	number of moles	n
106	mole fraction	x . . . X, y
107	molality	m
108	concentration	c
109	molar concentration of substance B	c_B, [B], c(B)
110	molecular concentration	C
111	partition function	Q
112	statistical weight	g . . . p
113	symmetry number	σ
114	characteristic temperature	Θ
115	diameter of molecule	σ . . . D
116	mean free path	l
117	diffusion coefficient	D
118	osmotic pressure	Π
119	surface concentration	Γ

Mechanical and related quantities

	Quantity	Symbol
201	force	F
202	force due to gravity (weight)	G . . . W
203	moment of force	M
204	power	P
205	pressure	p, P
206	traction	σ
207	shear stress	τ
208	modulus of elasticity	E
209	shear modulus	G
210	compressibility	$\varkappa$
211	compression modulus ($1/\varkappa$)	K
212	viscosity	η
213	fluidity	φ
214	kinematic viscosity	ν
215	friction coefficient	f
216	surface tension	γ . . . σ
217	angle of contact	ϑ

Thermodynamic and related quantities

	Quantity	Symbol	
301	temperature	$\vartheta \ldots t$	
302	temperature, absolute	T	
303	gas constant	R, $\boldsymbol{R}$	
304	Boltzmann constant	k, $\boldsymbol{k}$	
305	heat	q, Q	
306	work	w, A	
		(1)	(2)
307	energy (Gibbs' ε)	$U \ldots E$	$E \ldots U$
308	entropy (Gibbs' η)	S	S
309	Helmholtz' free energy (Gibbs' ψ)	F	A
310	enthalpy (Gibbs' χ)	H	H
311	Gibbs' function (ζ)	G	$F \ldots G$
312	heat capacity	C	
313	specific heats	c_p, c_v	
314	ratio c_p/c_v	γ, $\varkappa$	
315	chemical potential	μ	
316	activity, absolute	λ	
317	activity (relative)	a	
318	activity coefficient	f, γ	
319	osmotic coefficient	g, φ	
320	thermal conductivity	λ	
321	Joule-Thomson coefficient	μ	

Recommended by IUPAP (without... E) (1)
European practice (1)
American practice (2)

Chemical Reactions

	Quantity	Symbol
401	stoichiometric number of molecules (negative for reactants, positive for products)	ν
402	standard equation of chemical reaction	$\Sigma\, \nu_B\, B = 0$
403	affinity ($-\Sigma\, \nu_B\, \mu_B$) of a reaction	A
404	equilibrium constant	K
405	equilibrium quotient or equilibrium product (of molalities)	Q
406	extent of reaction ($dn_B = \nu_B\, d\xi$)	ξ
407	degree of reaction (*e.g.* degree of dissociation)	α
408	rate constant	k
409	collision number (collisions per unit volume and unit time)	Z

Light

	Quantity	Symbol
501	Planck's constant	h, $\boldsymbol{h}$
502	» » divided by 2 π	$\hbar$
503	quantity of light	Q
504	radiant power, flux of light ($\mathrm{d}Q/\mathrm{d}t$)	Φ
505	luminous intensity ($\mathrm{d}\Phi/\mathrm{d}\omega$)	I
506	illumination ($\mathrm{d}\Phi/\mathrm{d}S$)	E
507	luminance	L, B
508	luminous emittance	H
509	absorption factor (fraction of incident radiant power which is absorbed)	α
510	reflection factor (fraction of incident radiant power which is reflected)	ϱ
511	transmission factor (fraction of incident radiant power which is transmitted)	τ
512	transmittance ($T = I/I_0$)	T
513	absorption (extinction) coefficient ($\varkappa lc = \ln (1/T)$	$\varkappa$
514	absorbance (extinction) ($A = \log_{10} (1/T)$)	A...E
515	absorptivity (specific absorbance) (decadic absorption or extinction coefficient)	a
516	molar absorptivity (molar decadic absorption or extinction coefficient) ($\varepsilon lc = A$)	ε
517	refraction index	n
518	refractivity	r
519	angle of optical rotation	α

Electricity and magnetism

	Quantity	Symbol
601	elementary charge	e, $\boldsymbol{e}$
602	quantity of electricity	Q
603	charge density	ϱ
604	surface charge density	σ
605	electric current	I...i
606	electric current density	J
607	electric potential	V
608	electric field strength	E
609	electric displacement	D
610	electrokinetic potential	ζ
611	capacity	C
612	permittivity (dielectric constant)	ε
613	dielectric polarisation	P
614	dipole moment	μ
615	electric polarisability of a molecule	α, γ
616	magnetic field strength	H
617	magnetic induction	B

618	magnetic permeability	μ
619	magnetisation	M
620	magnetic susceptibility	χ
621	resistance	R
622	resistivity	ϱ
623	self inductance	L
624	mutual inductance	M, L_{12}
625	reactance	X
626	impedance	Z
627	admittance	Y

Electrochemistry

	Quantity	Symbol
701	Faraday's constant (the faraday)	F, **F**
702	charge number of an ion, plus or minus	z
703	degree of electrolytic dissociation	α
704	ionic strength	I...μ
705	electrolytic conductivity (specific conductance)	$\varkappa$
706	equivalent or molar conductance of electrolyte or ion	Λ
707	transport number	t, T
708	electromotive force	E
709	overpotential	η

SYMBOLS FOR SUBSIDIARY QUANTITIES

It is much more difficult to make detailed recommendations on symbols for subsidiary quantities than on symbols for the principal quantities. The reason is the incompatibility between the need for specifying numerous details and the need for keeping the printing reasonably simple. Among the most awkward things to print are superscripts to subscripts and subscripts to subscripts. Examples of symbols to be avoided are

$$\Lambda_{\mathrm{NO}_3^-} \text{ and } H_{25^\circ\mathrm{C}}$$

The problem is vastly reduced if it is recognized that two different kinds of notation are required for two different purposes. In the formulations of general fundamental relations the most important requirement is a notation easy to understand and easy to remember. In applications to particular cases, in quoting numerical values and in tabulation the most important requirement is complete elimination of any possible ambiguity even at the cost of an elaborate notation.

The advantage of a dual notation is already to some extent accepted in the case of concentration. The best notation for formulating the laws of homogeneous chemical equilibrium is something such as

$$\mathrm{A} + \ldots \rightleftharpoons \mathrm{L} + \ldots$$

$$\frac{c_{\mathrm{L}}\ldots}{c_{\mathrm{A}}\ldots} = K_c$$

$$\frac{m_{\mathrm{L}}\ldots}{m_{\mathrm{A}}\ldots} = K_m$$

but when we turn to a particular example it is better to use a notation such as

$$Br_2 + H_2O \rightleftharpoons HOBr + H^+ + Br^-$$
$$\frac{[HOBr]\,[H^+]\,[Br^-]}{[Br_2]} = K_c$$
$$K_c(25\ °C) = 6 \times 10^{-9}\ \text{mole}^2\ l^{-2}$$

Once the principle of dual notation is accepted, its adaptibility and usefulness become manifest in all fields of physical chemistry. It will here be illustrated by just a few examples.

The general relation between the equivalent conductance of an electrolyte and the equivalent conductance of the two ions is written most simply and most clearly as

$$\Lambda = \Lambda^+ + \Lambda^-$$

but when it comes to giving values in particular cases a much more appropriate notation is

$$\begin{aligned}
\Lambda(\tfrac{1}{2}\,Mg^{++}) &= 53\ \Omega^{-1}\ \text{cm}^2\ \text{equiv}^{-1}\ \text{at}\ 25\ °C\\
\Lambda(Cl^-) &= 76\ \Omega^{-1}\ \text{cm}^2\ \text{equiv}^{-1}\ \text{at}\ 25\ °C\\
\Lambda(\tfrac{1}{2}\,MgCl_2) &= 129\ \Omega^{-1}\ \text{cm}^2\ \text{equiv}^{-1}\ \text{at}\ 25\ °C\\
\Lambda(MgCl_2) &= 258\ \Omega^{-1}\ \text{cm}^2\ \text{mole}^{-1}\ \text{at}\ 25\ °C
\end{aligned}$$

In both notations the meaning of the symbols is so obvious and so well suited to the purpose that it is hardly necessary even to define them.

Again partial quantities are most simply denoted by the use of a subscript, for example V for partial volume and the general relation between the partial volumes of the two components of a binary system is written most simply

$$n_1 \mathrm{d} V_1 + n_2 \mathrm{d} V_2 = 0 \qquad (T, P\ \text{const.})$$

and this relation holds whether the partial volumes V_1, V_2 are expressed per mole or per gram or per kilogram according as the quantities n_1, n_2 are measured in moles or grams or kilograms. When it is desired to emphasize the contrast between partial quantities, which are intensive, and the extensive properties from which they are derived, this may be achieved either by use of a bar over the symbol or by use of the corresponding lower case letter. Thus in these notations

$$n_1\,\mathrm{d}\overline{V}_1 + n_2\,\mathrm{d}\overline{V}_2 = 0 \qquad (T, P\ \text{const.})$$
$$n_1\,\mathrm{d}v_1 + n_2\,\mathrm{d}v_2 = 0 \qquad (T, P\ \text{const.})$$

But when it comes to specifying values a completely different notation is called for such as

$$\begin{aligned}
V\ (K_2SO_4,\ \text{aq.},\ 0.1\ \text{M},\ 25\ °C) &= 48\ \text{ml mole}^{-1}\\
&= 24\ \text{ml equiv}^{-1}\\
&= 0.27\ \text{ml g}^{-1}
\end{aligned}$$

Each kind of notation is appropriate to its purpose.

Incidentally the notation for extensive and partial quantities need not be restricted to purely thermodynamic quantities but is also appropriate to such quantities as refractions. Thus if we define the refraction R (an extensive property) by

$$R = \frac{n^2-1}{n^2+2} V$$

then it becomes natural to denote the derived partial refractivity by R_i or $\overline{R}_i$ or r_i.*

Acknowledgement. The editors of Acta Chemica Scandinavica express their gratitude to IUPAC for permission to reprint the above pages from the union's Comptes-rendus de la dix-huitième Conférence, Zürich 1955, pp. 92–98.

* This paragraph has been approved in principle but not in detail by the Commission.