THE enH DECIMAL SCALE FOR EXPRESSING HYDROGEN-ION CONCENTRATION

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A practical system for expressing hydrogen-ion concentration, the enH decimal scale, within the range of th pH scale has been devised in order to simplify statistical analyses of variable hydrogen-ion data such as those from biological research. The pH scale which was originated by Sörensen (5), elucidated by Clark (2,3), recently reviewed by Bates (1), and its usual definition criticized by MacInnes (4) affords a serviceable system for some uses. However, this scale requires the conversion from negative logarithms to arithmetical values for statistical treatment and reconversion back to negative logarithms for expression.

Such conversions involve a degree of mathematical comprehension that may not be available in technical assistants who carry out the routine experiments and collect the basic data on hydrogen-ion concentration. Although the enH scale involves certain computations for mean values, the procedure can be carried out by personnel without the mathematical background required for the pH scale. Geometrical mean pH values, although adaptable for determination by technical personnel, are usually inappropriate. The purpose of this paper is to present the enH scale and its derivation and to correlate its values with pH values and hydrogen-ion normality values.

The enH decimal scale is an exponent-number system based upon centimicromicro normality ($c\mu\mu$ N. or 1×10^{-14} N.) of hydrogen-ion for the unit value. Its values are arithmetical entities which utilize a decimal number (n) multiplied by 10 raised to some power (e) to designate the hydrogen-ion concentration, i.e., $.10 \times 10^{8}$ for 1×10^{-7} N. of water under conditions for a dissocation constant of 1×10^{-14}.

In practical usage the decimal portion "n" may be limited to a two-place number. However, greater accuracy may be achieved by using a longer decimal number. For convenience and brevity, the exponent is written first as a whole number followed by the decimal point and number. Although such an expression is not conventional, the system is comprehended easily and is practical. By using the enH scale, it is possible to express arithmetically all the hydrogen-ion concentrations of the pH scale (pH 0.00 to 14.00) within fourteen whole number intervals of the enH scale (enH 1.10 to 15.10).

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TABLE 1.—EXAMPLES OF PROCEDURE FOR DETERMINING THE MEAN OF SOME ARBITRARY ENH VALUES BY THE USE OF SEVERAL COMMON EXPONENTS OF 10.

Values enH	Common exponents				
	10^9	10^8	10^7	10^6	10^5
9.25	.25	2.50	25.00	250.00	2500.0
8.50	.050	0.50	5.00	50.00	500.0
7.33	.0033	0.033	0.33	3.30	33.0
6.10	.0001	0.001	0.01	0.10	1.0
5.10	.00001	0.0001	0.001	0.01	0.1
Total	.30341	3.0341	30.341	303.41	3034.1
Mean 8.60682	.060682	.60682	6.0682	60.682	606.82

To determine the mean of a series of enH values that have the same whole number ("e" values), carry through the usual procedure on the arithmetical portion ("n" values) then combine the original whole number (common "e" value) with the resultant decimal mean. In cases of enH values with different whole numbers ("e" values), it is necessary to list the arithmetical portion ("n" values) according to an arbitrary common exponent (table 1). In this listing the arithmetical portion can and may have whole numbers as well as decimal values. After obtaining the mean of these listed numbers in the usual manner, the common exponent value and the mean decimal value are combined for the enH mean. The common exponent values do not change during the procedure of obtaining mean "n" values. If the mean value does not have its first number following the decimal point, shift the point to the right or left until this is the case. When the decimal point is shifted, the exponent value must be altered accordingly to maintain the same value. If shifted to the left, add to the exponent the number corresponding to the places moved. If to the right, subtract accordingly. Examples of the procedure are given in table 1. The mean value under each of the columns of common exponent converts to $.60682 \times 10^8$ which is enH 8.60682 or 8.61.

The relationship of the enH scale values to the pH values of zero mantissa and $c\mu\mu$ normality values is shown in table 2. The enH decimal values to five places that correspond to the pH mantissa are given in table 3. In converting enH values to pH values, change the whole number according to table 2 or figure 1. Then locate the arithmetical portion of the enH value in table 3 and read the pH mantissa (tenth in column 1 and hundredth in headings). For example, enH 8.19 (or enH 8.1905) converts to pH 7.72. In converting pH values to enH values, change the whole number according to table

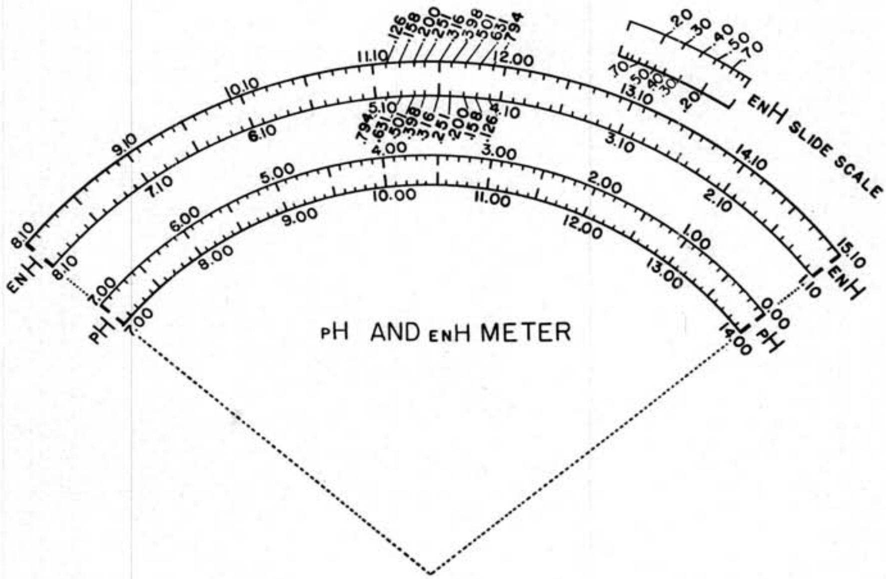

Fig. 1.—A dual pH and enH scale applicable for installation on electric meters for measuring H-ion concentration. It also illustrates the interrelationship of the two scales. The enH slide scale with logarithmic spacing of arithmetical numbers may be superimposed upon the enH scale for convenience in estimating arithmetical intervals.

2 or figure 1. Then from the pH mantissa in table 3 (tenth in column 1 and hundredth in the headings) locate the arithmetical number corresponding to the pH mantissa.

Transition from one "e" value to the next in series (above or below) does not involve fractional values of .10 (.01 - .09) when the decimal value is maintained with a number following the decimal point. The ascending hundredth value from .99 is 1.00 which converts to ("e" + 1) .10 whereas the descending hundredth value from .10 is .09 which converts to ("e" - 1) .90. There can be no "e" .00 value. There can be no arithmetical number of unity (1.00) or more except when used away from the exponent number such as computations involving only the "n" value (table 1). Any deci-

Table 2.—Relationship and Interconversion of pH, enH, and $c_{\mu\mu}$ Normality Values.

pH	enH	$c_{\mu\mu}$ normality H
14.00	1.10	$.1 \times 10^{1}$
13.00	2.10	$.1 \times 10^{2}$
12.00	3.10	$.1 \times 10^{3}$
11.00	4.10	$.1 \times 10^{4}$
10.00	5.10	$.1 \times 10^{5}$
9.00	6.10	$.1 \times 10^{6}$
8.00	7.10	$.1 \times 10^{7}$
7.00*	8.10*	$.1 \times 10^{8}$*
6.00	9.10	$.1 \times 10^{9}$
5.00	10.10	$.1 \times 10^{10}$
4.00	11.10	$.1 \times 10^{11}$
3.00	12.10	$.1 \times 10^{12}$
2.00	13.10	$.1 \times 10^{13}$
1.00	14.10	$.1 \times 10^{14}$
0.00	15.10	$.1 \times 10^{15}$

* Neutrality or hydrogen-ion concentration of water under conditions for a dissociation constant of 1×10^{-14}.

TABLE 3.—LOGARITHMIC INTERVALS OF THE enH DECIMAL VALUES INTERMEDIATE BETWEEN TWO ADJACENT WHOLE NUMBERS AND THE RELATIONSHIP OF THE VALUES TO pH MANTISSA.

For orientation, read arithmetical enH values (n) from right to left and top down, and read pH mantissa from bottom to top and left to right.

	pH mantissa									
	Hundredths									
Tenths	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
(1) .0	.10000(n)	......	......	......	......	......	......	......	......	...(n)
.9	.12590	.12303	.12023	.11749	.11483	.11221	.10965	.10716	.10472	.10233
.8	.15849	.15489	.15136	.14792	.14455	.14126	.13804	.13490	.13183	.12883
.7	.19953	.19499	.19055	.18621	.18198	.17783	.17379	.16983	.16596	.16219
.6	.25119	.24548	.23989	.23443	.22909	.22388	.21878	.21380	.20893	.20418
.5	.31623	.30903	.30200	.29513	.28841	.28184	.27543	.26916	.26303	.25704
.4	.39811	.38905	.38019	.37154	.36308	.35482	.34674	.33885	.33114	.32360
.3	.50119	.48978	.47864	.46774	.45709	.44669	.43652	42659	.41687	.40739
.2	.63096	.61660	.60256	.58885	.57544	.56235	.54955	.53704	.52481	.51287
.1	.79433	.77625	.75856	.74132	.72444	.70795	.69184	.67609	.66070	.64566
.0	(1).0000	.97724	.95500	93326	.91202	.89126	.87097	.85114	.83177	.81284

n = arithmetical decimal value to five places taken from J. Peters, Zehnstellige Logarithmen, Ersten Band, 1922.

mal number such as .01 or .005, etc., may be used for computations (table 1). These may even be used in combination with "e" but they present irregularities of notation in a series of enH values. For uniformity of expression and continuity of the scale, it is necessary to shift the decimal point so that a number always follows the decimal point.

The proposed enH decimal scale is for the sole purpose of expressing hydrogen-ion concentrations and does not relate to methods or accuracy of measurement. It combines the simplicity of notation of the pH scale with an arithmetical expression of normality. Consequently, the values in the enH scale may be treated statistically without conversion and reconversion. The enH scale also provides, as does the pH scale, for the convenience of plotting large differences in hydrogen-ion concentrations within a small space when logarithmic intervals or log. paper spacings are used for the decimal portion ("n" values) of the scale. (The "e" values are logarithmic.) It also provides a means of expression in which values are directly proportional to the concentration of hydrogen-ions. This is in contrast to the confusing pH scale in which the values are inversely proportional to the concentration of hydrogen-ions.

The pH scale offers further confusion when pH without numerical values is used as a noun qualified by adjectives such as higher, highest, lower, lowest, etc. Although the expression "higher pH" can mean only less acidity, the term presents a mental hazard because one must rationalize in order to comprehend the condition. Furthermore, the reader or listener may wonder whether the author or speaker has stated the condition correctly.

Although the pH scale is well established in scientific literature and usage and is generally installed on apparatus for measuring hydogen-ion concentration, the enH scale, if practical and serviceable, should not be barred from introduction and usage because of convention or habit of mind. However, "until a really fundamental and simple change is proposed, attempts to alter what has become established convention should be vigorously opposed and the convenience of pH should be preserved" (3). Introduction of the enH scale need not bring about a change in the system of designating hydrogen-ion concentration in the literature or in usage. If the hydrogen-ion meters were provided with a dual scale containing both the pH scale and enH scale, such as that illustrated in figure 1, the original reading could be made on the arithmetic scale for statistical analysis. Upon completion of the necessary statistical computation, the mean enH and other statistical values could be converted to the pH scale from tables 2 and 3 or figure 1 for final records. This procedure would eliminate the necessary conversion of many individual pH values for statistical treatment. If the hydrogen-ion data are not to be treated statistically, the original reading could be taken directly from the pH scale without using the enH scale.

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