United States Patent

Larson

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[54] NEGATIVE LOGARITHM-DECIMAL CONVERSION

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[52] **U.S. Cl.** **235/69, 235/78**
[51] **Int. Cl.** **G06c 27/00**
[58] **Field of Search** 235/69, 70, 77, 78, 116

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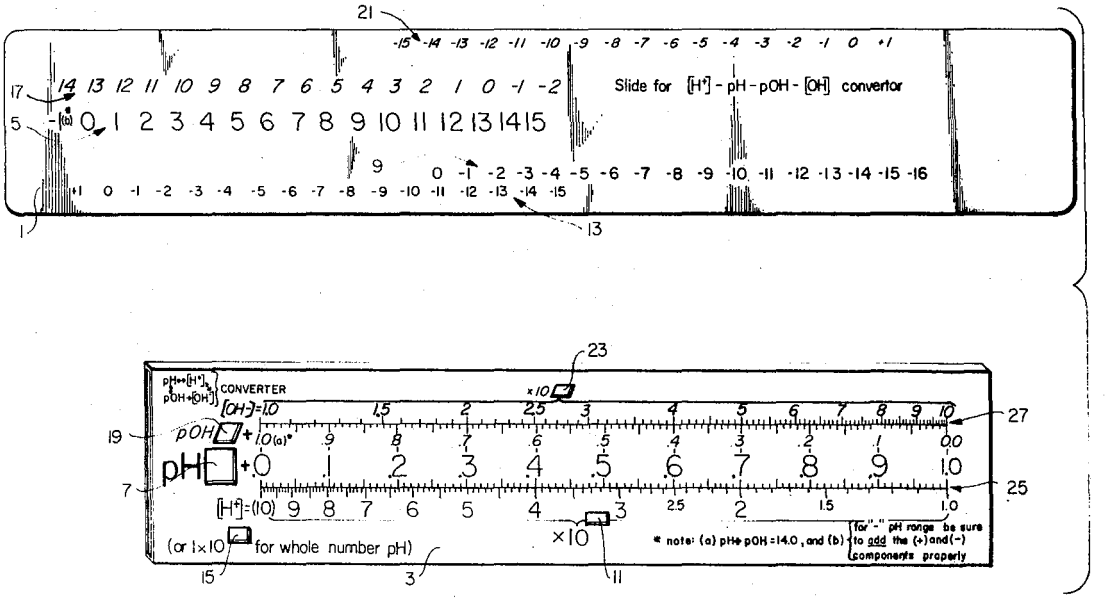
[57] **ABSTRACT**

Devices preferably having two scales which relate whole number negative logarithms to a negative power of 10 which is one more than the whole number, and two scales which relate logarithms less than 1 to a decimal expression of 10 times the reciprocal of the antilogarithm. The devices are useful as inexpensive and convenient tools to convert values of pH and other figures similarly expressed.

16 Claims, 4 Drawing Figures



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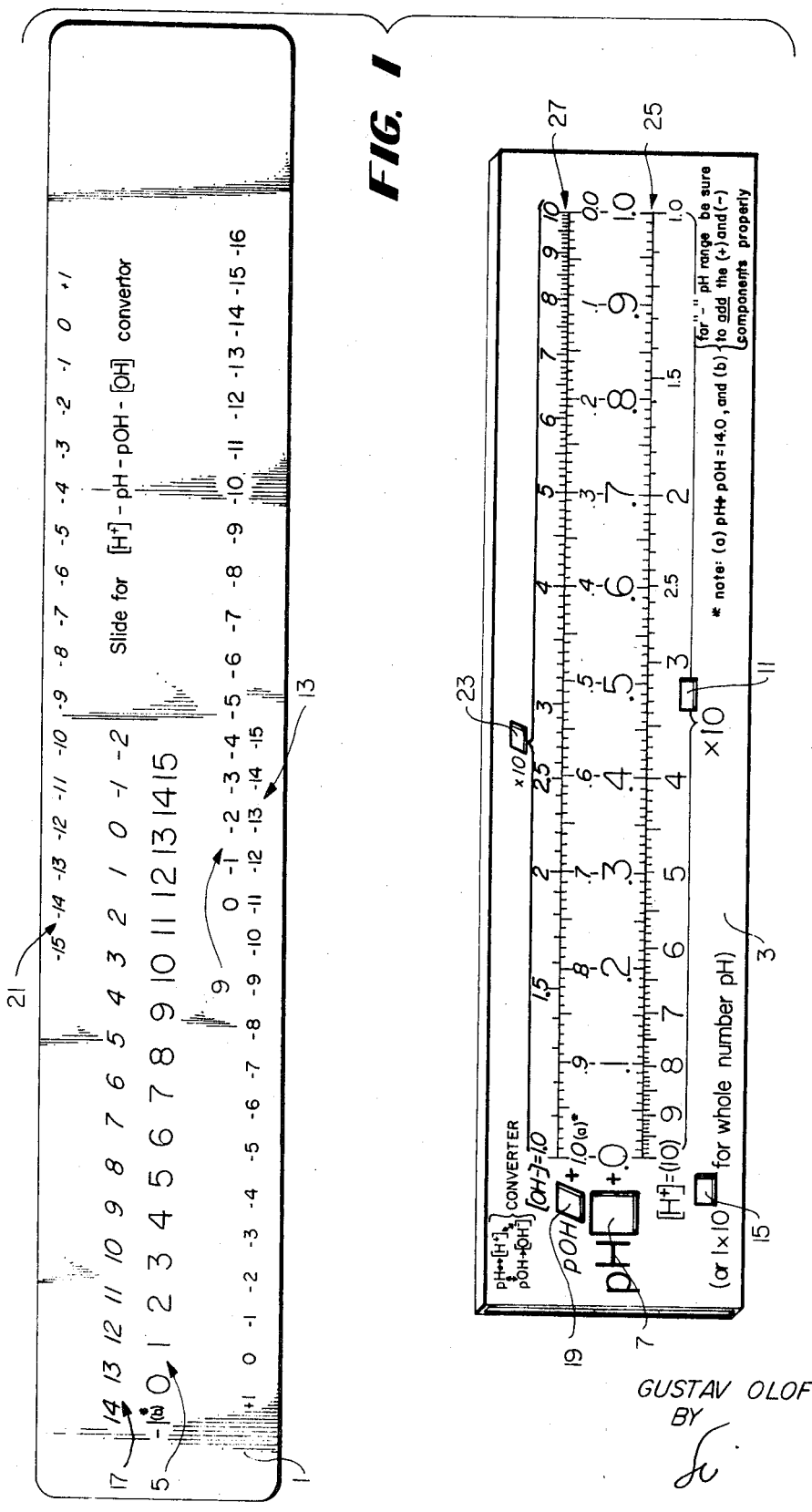
SHEET 1 OF 3

FIG. 1



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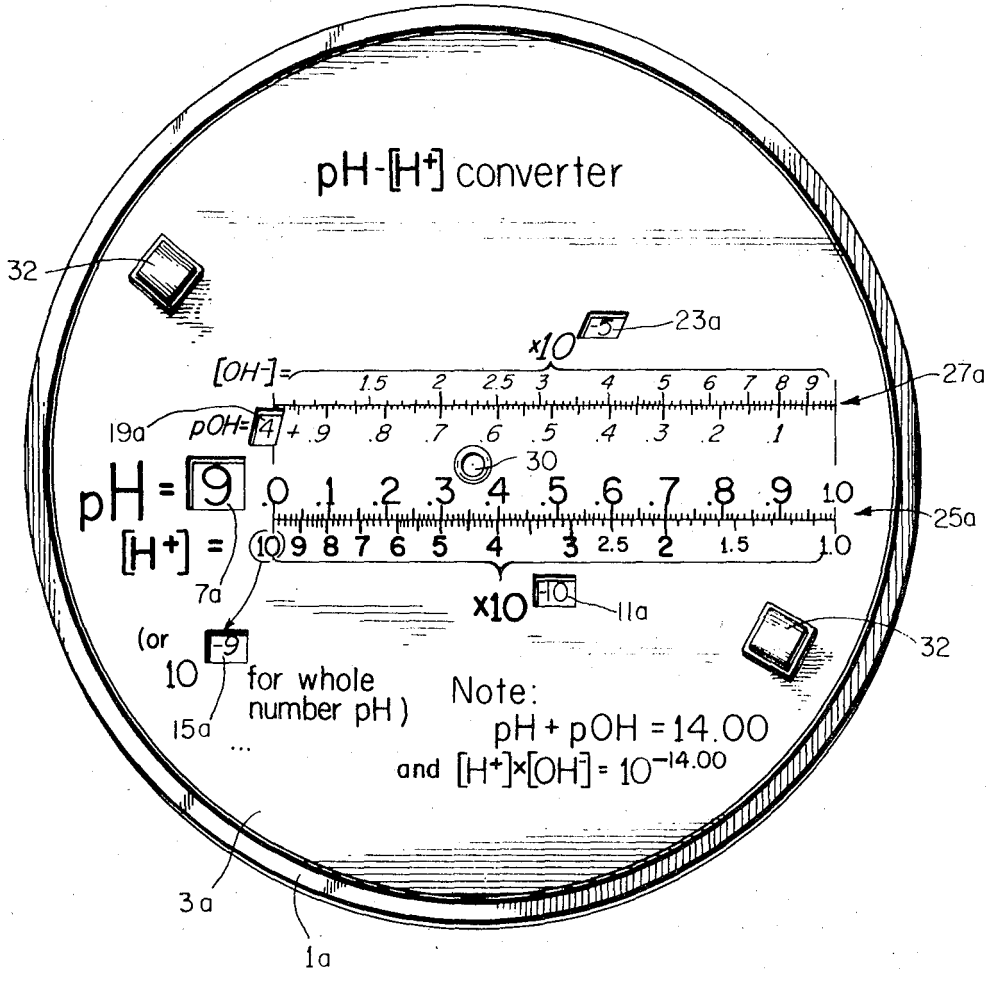

FIG. 2

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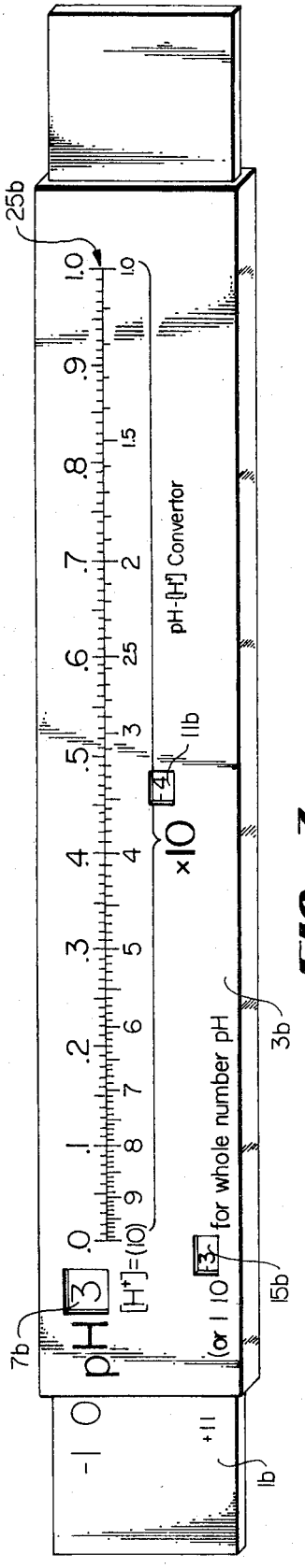

FIG. 3

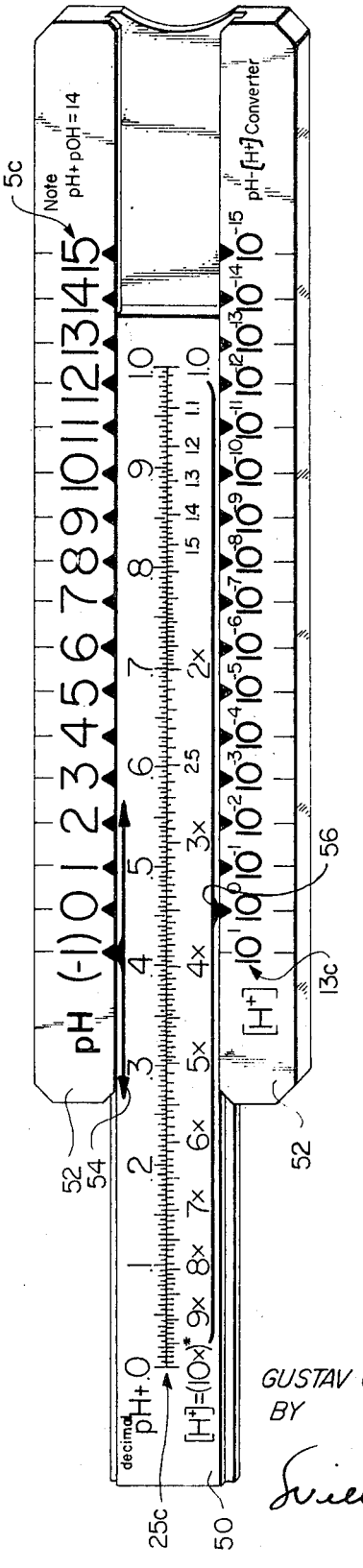

FIG. 4

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NEGATIVE LOGARITHM-DECIMAL CONVERSION

This invention relates to devices useful to assist in conversion between negative logarithms and decimal expression of quantities. The invention is particularly suited for working with pH values and analogous expressions.

A need exists for easier techniques to present concepts essential to problem solving in mathematics and chemistry. The handling of numbers is a very real stumbling block for many beginners, and efforts to persuade untrained persons to develop logical solution setups (based on unit labeling, balanced equations, mole concepts, "chemical mainstreets," and other such techniques) are often frustrated by the barrier encountered in "working out" the numerical answers. Even those fully trained in the mathematical manipulations involved may be burdened unduly by the performance of detailed pencil-and-paper solutions.

It is here proposed, therefore, that essential mathematical operations, especially those based on negative logarithms used for chemical calculations, be taught and performed in a way that will be efficient and will give students new insight for understanding and handling of numbers, so as to reduce (hopefully eliminate) the barrier of mathematical manipulation to the solving of chemical and other problems. For those still in training, facility in identifying and rewriting all numbers in full exponential forms is helpful in developing a facility for estimating answers, and prepares the student for a better understanding of pH and pK notation. The experience also leads more naturally to an understanding of logarithm tables and to the intuitive use of the slide rule in chemical calculations.

It is a primary object of this invention to provide an easily operated device for converting between negative logarithms and a decimal expression.

It is a further object of this invention to provide such a device which is economic and may be conveniently held and transported.

It is another object of this invention to provide such a device in the form of a slide rule, and which therefore may take various forms known or which may become known, some of which may be fabricated very economically.

Apparently, no device comparable in purpose or in arrangement is known in the prior art to make such mathematical conversions.

In accordance with this invention, a device is provided having a scale for the negative logarithm and a scale for the negative power of ten, with movable indicia adapted to visually relate each whole number logarithm with a power one greater in absolute value. The device also carries two other scales positioned to visually relate fractional parts of a logarithm to decimal expressions of 10 times the reciprocal of the antilogarithm of each fractional part.

These and other objects, features and advantages will become more apparent from the following discussion of four preferred embodiments, as illustrated in the accompanying drawings.

FIG. 1 illustrates a straight rule form carrying a large amount of conversion information, while still not displaying an inordinate or confusing amount of indicia;

FIG. 2 illustrates a circular rule form;

FIG. 3 illustrates a simplified straight rule form; and

FIG. 4 illustrates a more simplified straight rule form.

Each of the preferred devices is primarily designed for the purpose of converting between pH and corresponding decimal notation for $[H^+]$. The devices carry characteristic markings suited for this purpose. Additionally, the more elaborate rules carry similar indicia to convert between pOH and decimal notation.

The pH values for which the devices are designed are those which are commonly employed in abstract chemistry and which are defined as the negative of the logarithm of the effective hydrogen ion concentration $[H^+]$ in gram equivalents per liter. This definition may be fully expressed mathematically for the purpose at hand as $pH=-\log_{10}[H^+]$. The value of pOH are expressed by the same definition when hydrogen ion is replaced by hydroxide ion. The mathematical formula is

$pOH=-\log_0[OH^-]$. And, in every normal case, pH+pOH=14.00 and $[H^+]\times[OH^-]\times10^{14.00}$.

One set of two scales in the embodiments are related by the relatively movable indicia windows in the face or pointers so that pH and pOH whole numbers are indicated as being related to a negative number one greater in absolute value when the pH or pOH appears in conjunction with fractional pH or pOH values. This is set out in table 1. Additionally, table 1 also shows the proper conversion for whole number pH values, which is to a negative number of the *same* absolute value as the pH.

TABLE 1

pH (normal)	10 Exponent	10 Exponent (whole number pH	pOH	10 Exponent
/1	0	1	14	/15
0	/1	0	13	/14
1	/2	/1	12	/13
2	/3	/2	11	/12
3	/4	/3	10	/11
4	/5	/4	9	/10
5	/6	/5	8	/9
6	/7	/6	7	/8
7	/8	/7	6	/7
8	/9	/8	5	/6
9	/10	/9	4	/5
10	/11	/10	3	/4
11	/12	/11	2	/3
12	/13	/12	1	/2
13	/14	/13	0	/1
14	/15	/14	/1	0
15	/16	/15	/2	1

Each of the preferred embodiments carries a second set of scales positioned contiguously along their length so that points on one scale can be read on the other with a minimum of shifting of the direction of vision. To relate the fractional part of pH or pOH to decimal numbers between 1 and 10, the scales carry indicia positioned so that each of the pH or pOH values (from 0 to 1.0 on the scales) is opposite a value defined as $10^{x}/10$ (where x is the value of the corresponding pH or pOH fractional part). Since x varies between the limits 0 and 1.0, the ion concentration scale varies between 1.0 and 10.

For psychological familiarity and ease in interpolation between scales, the pH or pOH scales display quantities so that they appear linear (i.e., with equal distances between equal number amounts when interpreted as decimal values).

The device shown in FIG. 1 is preferred for applications suited to the use of more elaborate and expensive instruments and for applications in which the length of a straight rule is acceptable. Greater length of the scales provides increased accuracy in the reading of the scales. The device comprises an inner slide 1 movable within an outer shell 3. The outer shell has windows positioned to reveal numerals carried on the inner slide 1.

The inner slide 1 carries, starting near the left side, a line of numerals 5 as pH indicia equally spaced and varying from −1 and 15. On shell 3 near the left center a windowlike opening 7 approximately the size of the numerals in line 5 is positioned at a point where the various numerals of line 5 are displayed as the slide 1 is moved longitudinally.

A line of numerals 9 starts near the center of slide 1 below line 5 and is made up of exponent-of-10 indicia, for normal situations for hydrogen ion concentrations, equally spaced and varying from 0 and −16. Near the center of shell 3 a windowlike opening 11 approximately the size of the numerals in line 9 is positioned at a point where the various numerals of line 9 are displayed as the slide 1 is moved longitudinally.

A line of numerals 13 starts near the left of slide 1 near the bottom and is made up of exponent-of-10 indicia, for whole number pH situations, equally spaced and varying from 1 to

−15. Near the bottom left of shell 3 a windowlike opening 15 approximately the size of the numerals in line 13 is positioned at a point where the various numerals of line 13 are displayed as the slide 1 is moved longitudinally.

Just above line 5 slide 1 carries a line of slanted numerals 17 of somewhat smaller size than those of line 5, equally spaced and varying from left to right from 14 to −2, constituting pOH indicia. On shell 3 just above the left center a windowlike opening 19 approximately the size of the numerals in line 17 is positioned at a point where the various numerals of line 17 are displayed as the slide 1 is moved longitudinally.

A line of numerals 21 starts near the center and top of slide 1 and is made up of exponent-of-10 indicia, for normal situations for hydroxide ion concentrations, equally spaced and varying from left to right from −15 to 1. Near the top center of shell 3 a windowlike opening 23 approximately the size of the numerals in line 21 is positioned at a point where the various numerals of line 21 are displayed as the slide 1 is moved longitudinally.

Openings 19 and 23, which are used for conversion of pOH, have slanted sides rather than square to be readily visually distinguishable from the openings used for pH conversion. All of the notations and figures can be slanted to emphasize this difference.

On the surface of shell 3 are carried indicia markings which clarify the function of the device and the interpretation to be placed on numbers appearing during operation. Thus, the boldest marking is that of "pH" appearing just next to window 7.

Just to the left of and partially beneath window 11 the indication "$x10$" is displayed, which, of course, serves as a reminder that the number appearing in window 11 is to be interpreted as an exponent of 10, the full value of which is to be multiplied times another value. The position is such that the number appearing in window 11 is positioned at the usual location of an exponent of the 10 permanently displayed.

Just to the left of and partially beneath window 15 the indication "(or 1×10"is displayed. On the right of window 15 the indication appears "for whole number pH)." This constitutes a reminder both of the function of the number in that window and of the fact that the use is only with whole number pH. The position is such that the number appearing in window 15 is positioned at the usual location of an exponent of the 10 permanently displayed.

Immediately to the left of window 19 are the markings pOH, which constitute a reminder that the numbers in window 19 represent pOH.

Window 23 is marked in a manner similar to that of window 11.

A feature of those embodiments having the pOH scales also is that corresponding pH and pOH for the same solution may be read at the same setting of the device. The pH scales and pOH scales are side by side and progress in opposite sense so that the indications change the same amounts opposite in sense during the setting of the device. This corresponds to the physical facts of acidity and alkalinity in a medium. Thus, in the devices, the setting for whole number pH component of 8 is accompanied by a display for whole number pOH component of 5. This is the proper indication for pH and pOH values also having fractional parts, since the two fractions would add to a total of 1.

Scale 25 extends along most of the length of shell 3 and carries indicia on both sides. Scale 25 is actually an upper scale and a lower scale side by side longitudinally which relate fractional parts of pH to decimal factors. The marks and numbers appearing which define the top indicia are representative of pH parts and are positioned along the line even with window 7 and the prominent marking "pH" next to that window. The plus sign to the right of window 7 is a visual reminder that the fractional parts are to be added to the values in window 7. The lower marks and numbers define decimal parts in the corresponding description of hydrogen ion concentration. Immediately to the left is the marking "$[H^+]=$" which indicates this. The pH numbers on scale 25 increase from left to right.

On the upper part displayed in less conspicuous printing is a second scale 27 which is also two scales sharing a common centerline which relate fractional parts of pOH to decimal factors. The marks and numbers appearing which define the bottom indicia are representative of pOH parts and are positioned along the line next to window 19 and the permanent marking "pOH" positioned at that window. The plus sign to the right of window 19 is a visual reminder that the fractional parts are to be added to the values in window 7. The top marks and numbers define decimal parts in the corresponding description of hydroxide ion concentration. The pOH numbers on scale 27 increase from right to left. Each scale 25 and 27 is visually related to the opening 11 and 23 associated with it by a bracket which appears to contain the scale and to point to the related opening. Scale 25 is associated with opening 11, and scale 27 is associated with opening 23.

The device of FIG. 1 is shown for purposes of illustration with the slide fully withdrawn. In practice the slide 1 normally need not be removed from shell 3. Operation of the FIG. 1 device will be explained with reference to the operation of the devices of FIGS. 2, 3 and 4, since the operation is essentially the same.

FIG. 2 can be considered to illustrate a device as in FIG. 1 with the scales positioned on circumferences centered on pivot 30, the numerals progressing counterclockwise where they progress left to right in FIG. 1. Parts corresponding to those in FIG. 1 are given the same number in FIG. 2 followed by *a*. Two nubs 32 extend outward slightly to facilitate movement of the round, flat outer disk 3*a* of sturdy, thin paper. The bottom indicia is carried by a flat bottom disk 1*a* of sturdy, thin paper.

The device of FIG. 2 is shown positioned to convert hydrogen ion concentrations between 10^{-9} and 10^{-10}. The circular form provides ease and economies in construction and a maximum length shorter than that of the FIG. 1 device. The size and corresponding accuracy of use of scales 25 and 27 are reduced somewhat.

The FIG. 3 device is simply a scaled down version of the FIG. 1 device in which any reference to pOH is deleted. Parts corresponding to those in FIG. 1 are given the same number in FIG. 3 followed by *b*.

The device of FIG. 3 is shown positioned to convert between hydrogen ion concentrations between 10^{-3} and 10^{-4}. The reduced number of scales of FIG. 3 device provides for a smaller device with corresponding saving in fabrication and space occupied. The device also is somewhat less complicated to unfamiliar users than the devices having elements to also convert for hydroxide ions.

The device of FIG. 4 is a straight rule having the advantages of such and is quite simple and inexpensive to fabricate. Parts corresponding to those in FIG. 1 are given the same number in FIG. 4 followed by *c*.

The device of FIG. 4 is shown positioned to convert between hydrogen ion concentration between 10^1 and 1. Both scales above the center are for pH while both scales below the center are fro hydrogen ion concentration. The scale 25*c* is carried on the center slide 50, which is mounted at the edges to the outer shell 52 for longitudinal sliding movement. The indicia "pH" appears on the left side of the top part of scale 25*c*, indicating the scale at that level and above are representative of pH. The top scale also is marked pH. The indicia $[H^+]$ appears on the left side of the bottom part of scale 25*c*, indicating the scale at that level and below are representative of hydrogen ion concentration. The bottom scale also is marked $[H^+]$.

A top pointer 54 is inscribed on the top of the center slide 50 and points to a whole number pH value. A bottom pointer 56 similarly appears on the bottom of slide 50 and points to an exponential value partially defining $[H^+]$ as a power of 10.

TECHNIQUE AND REPRESENTATIVE CONVERSIONS

To convert from pH to $[H^+]$, the whole number part of the pH is designated in the appropriate manner for the device used. For the window devices of FIGS. 1–3, the slide **1**, **1***a*, **1***b* is moved to bring the whole number of the pH to a point at which that number is displayed in window **7**, **7***a*, **7***b*. For the FIG. **4** device, the slide **50** is moved longitudinally until the top pointer **54** is at the mark in the scale **5***c* which corresponds the the whole number of the pH.

With the whole number of the pH so designated, the exponent of ten value for hydrogen ion concentration may be read directly from the designation point for that item. For the window devices of FIGS. 1–3, this exponent in normal situations appears in window **11**, **11***a*, **11***b*. For the FIG. **4** device, the exponent is read from the bottom scale **13***c* as the value indicated by the bottom pointer **56**.

To complete the $[H^+]$ value, the decimal part is read directly from the conversion scale **25**, **25***a*, **25***b*, **25***c*. The fractional part of the pH is found on the pH indicia of scale **25**, **25***a*, **25***b*, **25***c* and the corresponding decimal value is read from the $[H^+]$ scale at the same longitudinal point at which the pH part is defined.

Where a pH value is negative, it is first rearranged by addition and subtraction of the parts making up the number (as logarithms in general may be so manipulated) so as to have a positive fractional part. For example, a pH of −0.60 is rearranged to −1+0.4. The same steps are then followed for both the whole number part and the fractional part.

Of course, with the FIGS. **1**, **2** and **3** devices whole number pH values may be covered directly without reference to scale **25**, **25***a*, **25***b*, **25***c* by reading that value directly from windows **15**, **15***a*, **15***b*.

Conversion from $[H^+]$ to pH is the reverse of the above procedure.

The number is first rewritten following the general rules for manipulation of decimal numbers to appear as a positive decimal number between one and less than 10 multiplied by 10 to a whole number power. The exponential value of that description is then indicated by, for the FIGS. **1**, **2**, **3** devices, positioning that value in window **11**, **11***a*, **11***b*. For the FIG. **4** device, that exponential value is designated by moving slide **50** until the bottom pointer **56** is directly at the indicia for that value. The whole number part of the corresponding pH is then read from windows **7**, **7***a*, **7***b* for the FIGS. **1**, **2**, **3** devices, and, for the FIG. **4** device from the top scale where indicated by the top pointer **54** on slide **50**.

To complete the pH value, the decimal number is read directly from the conversion scale **25**, **25***a*, **25***b*, **25***c*. The decimal part is found on the $[H^+]$ indicia of scale **25**, **25***a*, **25***b*, **25***c* and the corresponding pH value is read from the pH scale at the same longitudinal point at which the $[H^+]$ part is defined.

The pOH to $[OH^-]$ values are converted in essentially the same way. To convert from pOH to $[H^-]$, the whole number part of the pOH is brought to appear in the designation window **19**, **19***a*. While the whole number pOH so designated, the exponent of 10 value for hydroxide ion concentration is read directly from the designation window **23**, **23***a*.

To complete the $[OH^-]$ value, the decimal part is read from the conversion scale **27**, **27***a*. The fractional part is found on the pOH indicia of scale **27**, **27***a* and the corresponding decimal value is read from the $[OH^-]$ scale at the same longitudinal point at which the pOH part is defined.

Conversion from $[OH^-]$ to pOH is the reverse of the above procedure. The number is first rewritten as a positive decimal number between one and less than 10 multiplied by 10 to a whole number power. The exponential value of that description is then brought to the window **23**, **23***a* and the whole number part of the corresponding pOH is then read from window **19**, **19***a*.

To complete the pOH value, the decimal number is read directly from scale **27**, **27***a*. The decimal part is found on the $[OH^-]$ indicia of scale **27**, **27***a* and the corresponding pOH value is read from the pOH scale at the same longitudinal point at which the $[OH^-]$ part is defined.

Where a pOH value is negative, it is first rearranged by addition and subtraction proper for logarithms so as to have a positive fractional part (e.g., a pOH of −0.60 is rearranged to −1+0.4). The same steps are then followed for both the whole number part and the fractional part.

Numerical examples of such conversion will be considered with reference to the various settings of devices shown in FIGS. **2**, **3** and **4**.

With reference to FIG. **2**, a pH of 9.52 is converted as follows. The whole number of the pH, 9, is positioned in window **7***a*. The value 10^{-10} is then read directly from window **11***a*. The fractional part of the pH, 0.52, is located on the top half of scale **25***a*. The corresponding decimal value, approximately 3.02, is read from that location on the lower half of scale **25***a*. The pH value 9.52 is thereby converted to the decimal expression 3.02×10^{-10} describing the hydrogen ion concentration.

With reference to FIG. **2**, a pOH of 4.25 is converted as follows. The whole number of the pOH, 4, is positioned in window **19***a*. The value 10^{-5} is then read directly from window **23***a*. The fractional part of the pOH, 0.25, is located on the bottom half of scale **27***a*. The corresponding decimal value, approximately 5.6, is read from that location on the upper half of scale **27***a*. The pOH value 4.25 is thereby converted to the decimal expression 5.6×10^{-5} for the hydroxide ion concentration.

With reference to FIG. **3**, a hydrogen ion concentration of 0.000489 is converted to pH as follows. The number is rearranged by inspection to 4.89×10^{-4}. The −4 numeral is brought to appear in window **11***b*. The value 3 is then read directly from window **7***b*. The numeral part of the $[H^+]$, 4.89. is located on the bottom half of scale **25***b*. The corresponding fractional part of the pH, approximately 0.311, is read from that location on the upper half of scale **25***b*. The hydrogen ion concentration of 4.89×10^{-4} is thereby converted to the pH value of 3.311.

With reference to FIG. **4**, a pH of −0.891 is converted as follows. The number is rearranged by inspection to -1×0.109. Slide **50** is then moved longitudinally until the top pointer **54** is at the mark at the pH scale indicating −1, the whole number of the pH. The value 10^0 is read directly from the location on the bottom scale indicated by bottom pointer **56** on slide **50**. The fractional part of the pH, 0.109, is located on the top half of scale **25**. The corresponding decimal value, approximately 7.8, is read from that location on the lower half of the scale **25***c*. The pH value −0.891 is thereby converted to the decimal expression 7.8 (10^0 being equal to 1) for the hydrogen ion concentration.

It will be recognized that the several forms of the invention shown are in may respects equally advantageous and in other respects differ in features and advantages while still employing the substance and contribution of this invention. It will be apparent that devices can take other forms, some of which may be developed in the future, but all of which are within the basic substance and contribution of this invention. It will also be apparent that various separate features and elements of this invention may be employed, whether for limited purposes or at the sacrifice of optimum advantages, but nevertheless within the basic substance and contribution of this invention. Accordingly, the patent coverage granted should not be limited by the preferred embodiments disclosed, but should be as provided by law with particular reference to the accompanying claims.

What is claimed is:

1. A device to convert between negative logarithms and decimal expressions of quantities comprising

a first scale for said logarithms, a second scale for negative powers of ten in said decimal expression, and movable indicia adapted to visually relate each whole number represented on said first scale to a number represented on said second scale which is one greater in absolute value than said whole number, and

a third scale and a fourth scale positioned with respect to each other to visually relate fractional parts of said logarithms to decimal expressions of ten times the reciprocal of the antilogarithm of each of said fractional parts.

2. The device as in claim 1 also comprising an additional scale for negative powers of ten in said decimal expression, and in which said movable indicia is also adapted to visually relate each whole number represented on said first scale to a number represented on said additional scale which is the same in absolute value as said whole number.

3. The device as in claim 1 also comprising a fifth scale for said logarithms, and a sixth scale for negative powers of 10 in said decimal expression, and in which said movable indicia is also adapted to visually relate each whole number represented on said fifth scale to a number represented on said sixth scale one greater in absolute value than said whole number, said first scale and said fifth scale being positioned so that movement of said movable indicia so as to designate a value changing one amount on one of said first scale and said fifth scale will designate a value changing the same amount in the opposite sense on the other of said first scale and said second scale.

4. The device as in claim 3 also comprising a seventh scale and an eighth scale permanently positioned with respect to each other to visually relate fractional parts of said logarithms to decimal expression of 10 times the reciprocal of the antilogarithm of each of said fractional parts.

5. The device as in claim 4 also comprising a ninth scale for negative powers of 10 in said decimal expression, and in which said movable indicia is also adapted to visually relate each whole number represented on said ninth scale which is the same in absolute value as said whole number.

6. The device as in claim 1 in which said first scale and said second scale are on a slide adapted for movement relative to a part having two window openings, one operative with said first scale and one operative with said second scale, to display in one said window individual numerals of said first scale and in the other window individual numerals of said second scale, to provide said visual relationship.

7. The device as in claim 6 in which said third scale and said fourth scale are on said part having windows in the form of two groups of markings contiguous longitudinally.

8. The device as in claim 7 in which said slide is straight.

9. The device as in claim 7 in which said slide is pivoted for circular movement.

10. The device as in claim 2 in which said first scale, said second scale, and said additional scale are on a slide adapted for movement relative to a part having three window openings, one operative with said first scale, one operative with said second scale, and one operative with said additional scale, to display individual numerals of said first scale, said second scale, and said additional scale, to provide said visual relationships.

11. The device as in claim 3 in which said first scale, said second scale, said fifth scale, and said sixth scale are on a slide adapted for movement relative to a part having four window openings, one operative with said first scale, one operative with said second scale, one operative with said third scale, and one operative with said fourth scale, to display individual numerals of said first scale, said second scale, said fifth scale, and said sixth scale, to provide said visual relationships.

12. The device as in claim 5 in which said first scale, said second scale, said fifth scale, said sixth scale, and said ninth scale are on a slide adapted for movement relative to a part having five window openings, one operative with said first scale, one operative with said second scale, one operative with said fifth scale, one operative with said sixth scale, and one operative with said ninth scale, to display individual numerals of said first scale, said second scale, said fifth scale, said sixth scale, and said ninth scale, to provide said visual relationships.

13. The device as in claim 12 in which said slide is straight.

14. The device as in claim 1 in which a slide movable with respect to a member carrying said first scale and said second scale is positioned between said first scale and said second scale for sliding movement and carries pointing indicia to provide said visual relationship.

15. The device as in claim 14 in which said third scale and said fourth scale are carried on said slide.

16. The device as in claim 15 in which said third scale and said fourth scale are in the form of two groups of markings contiguous longitudinally.

* * * * *