The Relative Hydrogen Score, aka the rH Score

also: Care of pH and ORP Electrodes

Notes, Comments and Resources on ORP, pH , Relative Hydrogen (rH) Score, Clark's Rendering of the Nernst Equation for Calculation of rH; also: care and use of pH and ORP probes

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Relative Hydrogen Score, or rH: Clark's Rendering of the Nernst Equation for Determining Relative Hydrogen (rH, aka rH2) from pH and ORP Measures

Abstract
Discusses a version of the Nernst equation posited by Clark in 1923 for computing a true relative hydrogen reducing power score (rH score, aka rH2 score) from examination of both pH and ORP; often cited by deClerck (aka DeClerk; circa 1950) for beer brewing measures in a brewing textbook. Includes samples of some widely used rH formulas and the most accepted ones.

Introduction
The relative hydrogen scale was first proposed by Clark in 1923 to the scientific community (mostly inorganic chemists) as a means of measuring the true reducing power of hydrogen present in an aqueous solution, based upon a variation of the Nernst equation. The relative hydrogen, or rH (aka rH2), scale is a scale which measures true reducing power of simple compounds (very low molecular weight antioxidants) in aqueous solution. Let us note here that complex biochemical reducing agents, for example, antioxidants such as vitamin C, vitamin E, alpha lipoic acid or Coenzyme Q10 (ubiquinone) will not necessarily, when in aqueous solution, influence pH and particularly, ORP, in such a way as to render a true measure of their reducing (antioxidant) power; this is due to the fact that their antioxidant activity is optimal only for certain energy levels or levels of complexity, and outside those levels (e.g., simply dissolved in water), the reducing power may not be "released". To return to the topic of rH: In other words, unlike ORP, which yields a rough indicator of the amount of hydrogen reducing power available, but which is highly dependent upon the untoward and undesired effects of pH (e.g., the H+ ion, or hydrogen proton, which, when present in quantity, makes substances acidic), the rH yields a true index of hydrogen reducing power available, fully compensated for pH, to allow removal of all influence of the H+ ion (which, simply speaking, makes a substance acidic if present in quantity.)

More About the Scale
The rH scale employs the same logarithmic Bar scale used to express gas pressure in terms of order of magnitude, and the rH scale runs from 0 to 42; 28 is mid-point (balance), below 28 is reducing, above 28 oxidizing. An rH of 42 indicates 1 atmosphere (1 ATM) of partial pressure of O and a –42 exponent partial pressure of H, while an rH of zero (0) indicates 1 ATM partial pressure of H (adjusted for skewing effects of the H+ [aka "acid"] ion) and a –42 exponent partial pressure of O. Therefore, an rH score of 0 would indicate maximum possible reducing (antioxidant) power, while a score of 42 would indicate the maximum possible oxidizing environment.

So, rH yields a hydrogen proton-unbiased measure of absolute reducing potential of a substance; eliminating effects due to pH. rH is log1/hydrogen partial pressure; a one unit change in rH indicates a 10X change. E.g., a shift on the Barr scale of rH from a score of 27 to one of 26 indicates a 10X increase in reducing power. rH 28 = H partial pressure (pp) of 10^-28 atmospheres, an rH 11 = H pp is 10^-11 atmospheres, and a 0 rH is the rH value of pure hydrogen at STP. Again, as noted above, an rH score of 0 would indicate maximum possible reducing (aka "antioxidant") power, while a score of 42 would indicate the maximum possible oxidizing environment.

Nonetheless, ORP and better, rH, have found some degree of acceptance for many years in the fields of high-end aquarium keeping, wine and beer brewing, food storage and food safety as an indicator or relative antioxidant ability, and, since the mid-to-late 90's; in some sectors of the nutritional antioxidant field as an indicator of the same as well. It is somewhat important to note that ORP and rH scores have also been used to some extent for many years in the groundwater and waste water remediation fields as well as measures of relative oxidation or reducing ability of water.

rH or rH2?
At times throughout it's history, the scale in question has been referred to as the rH2 scale, which would denote that it is particularly, or even solely, indicative of the presence of dissolved diatomic hydrogen, aka H2 in solution. This is decidedly not true, and the scale is equally sensitive, if not more so, to the presence in solution of atomic hydrogen or the hydride ion, the latter usually not in free form, but rather "available" in the form of hydride ions, solvated water clusters, hydride ions in water cages, or very low molecular weight antioxidants. Yes, it is true that even some biochemical antioxidants with an MW over 150, such as many forms of Vitamin E, also function as an antioxidant by donating the hydride (H-minus ion) at the right time and place, but many of these molecules are so specific as to where and how they can and will donate the hydride

ion that they usually do not influence rH score (or, concomitantly, ORP measures) significantly.

An Important Note About rH (or ORP) and Antioxidant Power
Although it may be noted again later in this paper, I feel that it is extremely important to note that rH is only a rough and correlative indicator of true antioxidative (aka reducing) power of a solution. While it is true that many of the simple hydride antioxidants, such as atomic hydrogen or the hydride in in water cages, or other simple hydride species, and many lighter molecular weight (MW) antioxidants with MW below about 150 will often appreciably reflect their antioxidant activity via a low ORP and low rH score (indicating high antioxidant ability), it is equally true that many higher MW antioxidants, with MW ranging from 150 to over 1,000 (some have MWs of up to 200,000 Dalton units...) will not necessarily have their antioxidant or reducing activity adequately reflected in ORP or rH score. This is because these biochemical antioxidants may be more specifically "tuned" to donate their free electron (or H- ion, as the case may be) in specific biochemical systems or at very specific energy levels, and will therefore not show much effect on ORP and rH score of "plain" unadulterated water.

The Simplified Variants of the Clark/Nernst Formula for Computing rH

- There have been a number of variant simplified formulas for computing rH from ORP and pH of aqueous solutions floating around the worlds of science and the related applied science fields for over 40 years. For the purposes of this paper, a "simplified formula" is any which has been rendered as a simple algebraic equation without any logarithmic functions. Particularly, there have been a number of variant simplified rH formulas appearing in a number of fields for many years since Clark published his two-part article in 1923 positing this measure based upon the Nernst equation. Some of the fields where rH (aka rH2) has been employed extensively are :

  - professional wine and beer brewing
  - homebrewing of beer and wine
  - nutritional antioxidant research
  - within the food processing industry, as a means of assessing redox state (e.g., antioxidant status and spoilage potential) of fruit juices, etc.
  - some sectors of alternative health diagnostic systems, especially Bioelectronics by Vincent (BEV), also known as Biological Terrain Analysis (BTA or BT)
  - inorganic chemistry of metals (oxidation and reduction)
  - biochemistry of metal oxidation or reduction
  - soil nutrient measurement and formulation, especially within the realms of organic farming/gardening
  - environmental waste water and remediation studies
  - ground water studies, including assays of surface waters, underground aquifers, water from deep wells, etc.
  - the high-end aquarium world

The Best Formula of the Lot
Although some of the variant simple formulas will be discussed below, most folks who are serious about the matter use the following formula or one very close to it for calculating rH from pH and ORP:

$$rH = ((ORP + 200) / 30) + (2 * pH)$$

And, this is the formula which I use in all my calculations, including those sample calculations shown in the **Samples table on the page on this site entitled *Sample rH Scores Calculated from ORP and pH.***
Actually, for greatest accuracy, the denominator of the fraction should really be 29.58, and the numerator function should likely be +205, but these are extremely minor matters.
This is essentially the formula used by Patrick Flanagan and his scientific colleague and co-author Cory Stephanson, also by many in the Western organic farming soil diagnostics field (e.g., Bob Pike of Pike AgriLabs, etc.), and by the famed beyond-organic farming expert Sigfried Lubke in Austria.

For some samples of rH scores calculated from various combinations of ORP and pH, please see the Samples table on the page on this site entitled *Sample rH Scores Calculated from ORP and pH*

This is the formula which I normally use for computing rH and which seems to be employed by most researchers whom I know, with extremely minor variations at times.
Since I have no patience for performing hand calculations, I have created a simple Excel spreadsheet with columns for name of batch or test, pH and ORP, and then a fourth column instantly calculates the rH from the ORP and pH.

Please note that manufacturers (e.g., WTW and others) of digital test equipment for rH, ORP and pH, and of calibration test solutions for ORP and rH, often use a simpler and less accurate formula. This is discussed to some extent in the section below entitled ***A Wide Range of Variant Formulas.***

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A Wide Range of Variant Formulas
The Clark/Nernst formula has been converted into a number of other variant simplified rH formulas over the years, some of which yield meaningful and rather accurate numbers and others of which yield near-nonsensical scores. Some of the mainstream and variant versions, with a few notes, appear below:

> *Generic:*
> Per numerous generic sources in a number of fields, the simplified Clark/Nernst equation for deriving rH from

pH and ORP is:
rH = (ORP / 30) + (2 * pH)
This yields a score which is somewhat higher than the true rH reading.

Patrick Flanagan:
Per Patrick Flanagan, the Clark equation for deriving rH from pH and ORP is:
rH = ((ORP + 200) / 30) + (2 * pH)
Patrick reports that the +200 is to adjust for a pure hydrogen reference standard, as well as temperature. He reports that the number should be 204 for 75 degrees F.
Please note that this is the formula which I usually use; see also notes below about the Siegfried Lubke formula, which is essentially identical….

The formula from Siegfried Luebke (aka Lubke or Leubke), the amazing Austrian organic farmer:
Per Bob Pike at Pike Agri-Lab Supplies (organic and sustainable farming supplier), the formula he was given years ago by Siegfried Lubeke, the near magical and mystical farmer in Austria, is:
rH = ((ORP + 210) / 30) + (2 * pH)
Lubke showed him this exact formula from a German-language book in his library, which is where Luebke found it originally. Bob was under the impression that the + 210 was the rendering of RT for 21 degrees C. It is not; rather, it is, as Patrick reports, an adjustment for a pure hydrogen electrode reference.
This formula is almost identical to Patrick's formula from Clark, except for the fact that Patrick employs +200 while Pike/Luebke employ +210 in the numerator of the fraction; this is simply related to temperature adjustment.

Incidentally, while on the topic of Luebke, in November 2003 I received a very helpful note from Steve Diver, the well-known organic farming and biodynamic farming consultant, and I have reproduced part of his letter below:

> "Fyi, Siegfried Luebke is the Austrian farmer who developed Controlled Microbial Compost. He is recognized as a self-taught genius in microbiology. Referring to him as the mystical farmer from Austria is a bit misleading. The Luebkes never talk about mystical things in their seminars; they are very practical and grounded in agronomics, microbiology, soil science, and organic farming methods. They use ORP as compost quality parameter.
>
> Fyi, there is a parallel between the microbial power of Clay-Humus, EM, BD and so on, in that all microbe farming systems are infused with and emanate a bioenergy field. Microvita theory based on P.R. Sarkar's work in India may be a unifying thread that links subtle energy practices to biology and physics.
>
> Fyi, Dr.Alberta Velimirov and other researchers in Europe have used the P-Value test to evaluate electrochemical properties of food. It is single value derived from pH, redox, and electrical conductivity." *[ed, note: This is extremely similar, if not identical to, the Biological Terrain Assessment (BT, or BTA) score created by followers of the work of Claude Vincent, the French hydrologist turned health trends statistician.]*

EIT formula from Microhydrin's Early Days:
The EIT folks – who did not reveal their exact rH formula – provided a list of pH/ORP/rH values for various common liquids to RBC, and these values were published on numerous RBC websites. Most of the calculated rH values agree closely with Patrick's formula above, but a few, especially at pH's below 6.5 and ORPs in the negative range, were very far off from all the results from any other equations. I suspect that they attempted to use either the formula from Patrick or from Lubke, but that they sometimes erred on their math; perhaps their program of Excel sheet had a bug…

Gage, O'Dowd and Williams Paper on Biological Removal of Iron and Manganese:
Per Gage and O'Dowd in web PDF file: "Biological Iron and Manganese Removal, Pilot and….", presented at the Ontario Water Works Association conference, 5/3/2001:
rH = (Eh / 0.029) + (2 * pH)
I suspect there is a major typographic error in the formula in the article, and that the first portion of the right hand part of the equation should read (Eh * 0.029) or (Eh / 29)… as it currently stands, the formula makes little sense, and yields nonsense numbers…! This formula simply does not seem to work even if ORP is adjusted to yield a "true" Eh score.

Formula Found in Several Places in Aquarium World Websites:
Per formula: Reef Central Aquarium website; the 6.67 constant added is for "dissolved oxygen":
rH = (ORP / 29) + (2 * pH) + 6.67
Strangely, the +6.67 function does much the same thing as adding +200 or +210 to the ORP in the numerator of the fraction… yielding an rH which is very close to the formulas (e.g., Flanagan, Lubke, etc.) which do this.

Per the Yokagawa ORP/pH/rH Meter Products Tech Info Sheet:
The Yokagawa spec sheet for their digital meter provides the basic formula as:
Eh (ORP) = 59.16 (2 * pH - rH)
which, using my rusty algebra, yields:
rH = 59.16 * (2 * pH) - ORP
which makes no sense at all to me or to anyone else who has seen it.…. maybe I am missing something…This formula simply does not seem to work even if ORP is adjusted to yield a "true" Eh score.

From the beer brewing world, largely from an article by deClerk circa the 1950s:
This one is really odd, and the method has been culled and reconstructed from various homebrew beer websites, old beer brewing texts, and a few old posts to homebrew beer list groups or forums, all of which seem to trace their lineage back to an article by DeClerk from the 1950s, apparently published in a beer brewing book. It appears to be a rather complex equation, which involves one measure of temperature and several separate measures of pH performed on the liquid, the latter with several different types of electrodes.

each using different reference metals in the electrode. Obviously, the purpose of this painstaking, tedious, puzzling and expensive exercise is to really derive a pH measure and a simulacra of an ORP measure. Perhaps when deClerk originated this measure in the 1950's, good ORP electrodes were hard to come by... Things are much easier nowadays, as we have access to good reliable pH electrodes and ORP electrodes.

Unmodified Nernst/Clark Formula, from Several Papers:
For reference purposes, Dr. Patrick Flanagan and Cory Stephanson report that the original Clark formula, from Clarks' 1923 paper is:

Eh = 1.23 – ((RT / F) pH) – (RT/ 4F) * ln (1 / Po)

For some samples of rH scores calculated from various combinations of ORP and pH, please see the Samples table on the page on this site entitled *Sample rH Scores Calculated from ORP and pH*

Notes:

where ORP or Eh or Eo or E = ORP in millivolts, 1.23 refers to potential of oxygen under 1 atm pressure, rH is defined as the negative logarithm of the oxygen pressure Po, or:
rH = -log Po

rH yields a hydrogen proton-unbiased measure of absolute reducing potential of a substance; eliminating effects due to pH.

rH is log1/hydrogen pressure; a 1 unit change in rH = 10X change. E.g., a shift from 27 to 26 = 10X increase in reducing power.

rH scale runs from 0 to 42; 28 is mid-point (balance), below 28 is reducing, above 28 oxidizing; rH 42 indicates 1 ATM O; rH 0 = 1 ATM H.

In plain English, an rH score of 0 would indicate maximum possible reducing (antioxidant) power, while a score of 42 would indicate the maximum possible oxidizing environment; a score of 28 is mid-point.

rH 28 = H partial pressure (pp) of 10^-28 atmospheres; an rH 11 = H pp is 10^-11 atmospheres. 0 rH is rH value of pure H2 at STP.

Care, Storage, Use and Cleaning of ORP and pH Electrodes (Probes)

Here are some fairly complete instructions for care, use and cleaning of pH and ORP electrode probes; they should also work for conductivity probes as well.

Caveat
I make and offer no guarantees as to the accuracy of usability of this information, although it has worked well for me. I take no responsibility for any results or lack or results, or any harm or injury from any caustic substance used in these procedures. Frankly and bluntly, if you are a stupid-head, you should should not be using pH or ORP probes in the first place, much less trying to clean them!

Origins of Instructions and Procedures
These procedures seem to be fairly standardized in the various lab equipment fields, although many equipment manufacturers will not call the cleaning compounds or solutions by their simple names, but rather will want to sell you the same stuff under their own brand name for a thousand times the price of what you could purchase it for under it's generic name. Your choice...
I have listed sources for all materials at the end of the post.

Storage
First, however, let us talk about how to store pH and ORP probes (and conductivity) between uses, since that is even more critical than occasional cleaning:
Storage and maintenance of probes after each use:

1) After each use, probes should be dipped in clean tap water and agitated to remove any contaminants or stray substances.

2) Then, the probes should always be stored wet, that is in water, and the water must never be distilled or (fully) de-ionized water (both of which are too "hungry" and will steal critical ions from the channels of the pH and ORP probes), but rather, only in plain tap water. Even better is to add a few percent (about 5% to 8%) of hydrochloric acid (HCL) to the storage soak water (keep away from kids and pets.) In any case, probe soak water should be emptied and refreshed occasionally, perhaps once per week or two or three.

3) Unless you have a specialized probe for which the manufacturer has suggested otherwise, ORP and pH probes should never be stored dry.

Cleaning of probes

1) Make sure probe has been wetted with tap water. Looking at probe area, clean the probe surfaces lightly with a soft or medium-soft brush; a small, soft toothbrush will do. Then rinse. Sometimes this step alone will remove enough of visible and invisible contaminants to restore probe to "good" (usable) use. However, at least

once per month or two or moderate to heavy use, it will be necessary to go on to one or more of the next steps as well:

2) Soak probe in a 25% to 80% solution of chlorine bleach (aka Clorox) in water (keep soak water away from kids or pets) for at least 15 minutes. Agitate or swirl probe at times to help circulate cleaning solution and remove contaminants. Sometimes this step and the preceding step alone will remove enough of visible and invisible contaminants to restore probe to "good" (usable) use. (For ORP probes, a good sign is if and when the ORP reading [of the solution] goes above +800, or better, even higher.)
Rinse in tap water when finished.
If readings are still funky or slow, it will be necessary to go on to one or more of the next steps as well:

3) Soak probe in a 10% to 30% solution of HCL in water for at least 5 to 15 minutes. Be sure to observe the usual precautions about mixing these substances, and please wear eye protection when mixing. BE SURE to keep any such acids or pre-mixed storage bottles of water/acid solution covered and away from kids and pets. (For pH probes, a good sign of cleanliness is if and when the pH reading [of the solution] goes down to about 1.1 or less, or better, even lower.) Sometimes this step and the preceding steps alone will remove enough of visible and invisible contaminants to restore probe to "good" (usable) use.
Rinse in tap water when finished.
If readings are still funky or slow, or "stuck" in one area, or if pH readings now seem too stuck in the acid range, it will be necessary to go on to the next step as well:

4) Soak probe in a 10% to 30% solution of potassium hydroxide (KOH) or sodium hydroxide (NaOH) in water for about 2 to 4 minutes. Be sure to observe the usual precautions about mixing these substances, and please wear eye protection when mixing. BE SURE to keep any such alkalis or pre-mixed storage bottles of water/alkali solution covered and away from kids and pets.
Rinse in tap water when finished.
This will usually take care of any remaining gunk or contaminants.

Use of pH Probes
Please note that for greatest accuracy, a pH probe should remain in the substance to be tested for about 3 minutes or longer, and even gently swirled or swished in the beginning of test. However, for pH readings, even the readings after 30 seconds will be fairly accurate unless the probe has some contaminant layers. Then, longer will be necessary.

Use of ORP Probes
Please note that for greatest accuracy, an ORP probe should remain in the substance to be tested for at least 15 to 30 minutes or longer, and even gently swirled or swished at the beginning of test. For ORP readings, even the readings after 3 minutes will be fairly accurate unless the probe has some contaminant layers (and most do!). Then, the full 15 to 30 minute soak will be necessary. See ***Warning About ORP Probes*** below!

Warning About ORP Probes
Please realize that almost all ORP probes which have been in use for more than a few hours without fanatical cleaning will usually have a thin layer of oxidized material on the electrode surfaces. Almost invariably, this thin contaminant layer will usually result in ORP readings which "pull' or regress, the readings toward the moderate oxidized range, usually toward the +300 to +450 mv. range. Further, these deposits will also slow settling time, making it take longer for the probe to yield a fairly stable reading (which may still be too high, or pulled toward the positive range. For several reasons, this is often not much of a problem when measuring oxidized samples in the range of +150 mv and above. However, for liquids with an ORP below +150, and particularly those in the reduced range, with an ORP below about -050, this phenomenon can result in very serious distortion or pulling of resultant ORP readings toward the positive or oxidized ranges.

Sources:

Chlorine bleach: supermarket. Be careful handling and storing it.
Hydrochloric acid: most hardware stores and home improvement stores. Often sold for scrubbing scale from toilets or for scrubbing concrete. Be careful handling and storing it.
Potassium hydroxide: lab supply house. Be careful handling and storing it. Usually easier to sue Sodium hydroxide, below...
Sodium hydroxide: hardware store, often sold as lye crystals or pellets. Read label to be sure it is pure NaOH. Be careful handling and storing it.

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