Introduction

This site explains the affect that Henry's Law in association with Le Chatelier's principle, Fick's Law, and Grahams Law have on the dynamic equilibrium of the net gaseous carbon dioxide in the Earth's atmosphere and dissolved carbon dioxide in the Earth's extensive biosphere, to wit: the ocean covers over 70% of the Earth's surface. This is a temperature dependent function.

Temperature increases always precede releases of CO_2 from water into the air. into the air. Decreases in temperature always result in greater concentration of dissolved CO_2 at the air/water surface boundary.

ClimateCite, a US 501(c)(3)compliant nonprofit educational and research institute has written and published this scientifically authoritative website which explains the physical chemistry of Henry's Law and its operation controlling and regulating the Earth's net CO_2 atmospheric content. It is structured for both advanced Ph.D. level scientists and scientifically lay people.

Mankind and its introduction of carbon dioxide (CO_2) into the atmosphere through his use of hydro- carbon based fuels (sometimes referred to as fossil fuels) does not and cannot increase the total net atmospheric CO_2 concentration. The term net atmospheric concentration means all remaining CO_2 in the atmosphere after introduction of all CO_2 from all sources, natural and anthropogenic, and absorption in the Earth's biosphere "sinks". Concepts such as the half-life of man's CO_2 are without scientific merit. Total net CO_2 atmospheric concentration is controlled and regulated solely by Henry's Law and subject to its variables including temperature which is the primary driver of CO_2 increases and decreases per period time. Just as Newton's Universal Law of Gravitation defines the mechanics of gravity, Henry's Law defines the dynamic equilibrium of gases in continuous contact with liquids, including for example CO_2 gas in the atmosphere in contact with Earth's ocean and other water bodies.

Henry's law states that at a constant temperature, the amount or concentration of a given gas that dissolves in a given type and volume of liquid is directly proportional to the partial pressure of that gas. Consumers experience Henry's law at work every day when a carbonated beverage is taken out of the refrigerators and slowly loses its carbonization fizz as it reaches room temperature. Henry's law 100% controls or regulates the Earth's atmospheric concentration of carbon dioxide (CO_2). As the surface temperature of a body of water increases it liberates CO_2. Conversely when that body of water decreases in temperature it absorbs CO_2. The Earth's surface is over 70% water. Like

Newton's laws of motion, acceleration, and gravity, Henry's law is just that; a constant law of physics.

Why is it that so many well qualified scientists including those with Ph.D. degrees in physics, chemistry, and geology do not discuss Henry's law and the fact that it is nature's CO_2 control mechanism and regulator? Unlike Newton's Universal Law of Gravity which is taught in grade school, Henry's Law is not taught in high school physics or chemistry and the vast majority of university undergraduate and graduate physics books do not discuss Henry's Law. Thus there is a critical hole in the scientific knowledge that leads to the confusion and misunderstanding of man's contribution of net atmospheric CO_2 and the related fictitious concept of AGW commonly called climate change. CO_2 is a fundamental building block of life.

Explanation of Henry's Law

The solubility of a gas in a liquid increases with increasing pressure. To understand this at the molecular level, imagine the following equilibrium established in a closed container fitted with a movable piston.

If the piston is pushed down (Figure 13.11b), the gas is compressed and its pressure increases. This causes the concentration of the gas molecules over the solution to increase, so the rate at which the gas dissolves is now greater than the rate at which it leaves the solution. Eventually, equilibrium is reestablished when the concentration of the gas in the solution has increased enough to make the rate of escape equal to the rate at which the gas dissolves (Figure 13.11c). At this point, the concentration of the gas in the solution is higher than before.
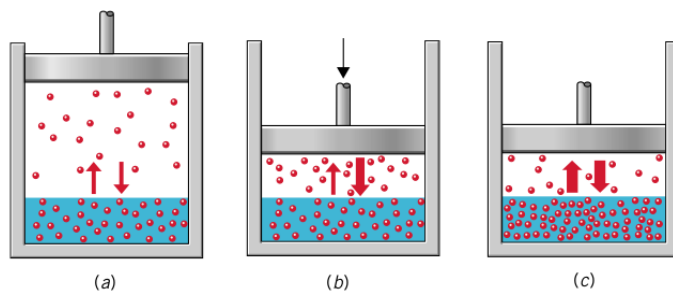
Figure 13.11 | **How pressure increases the solubility of a gas in a liquid.** (*a*) At some specific pressure, equilibrium exists between the vapor phase and the solution. (*b*) An increase in pressure upsets the equilibrium. More gas molecules are dissolving than are leaving the solution. (*c*) More gas has dissolved and equilibrium is restored.

Adapted from _Chemistry the Molecular Nature of Matter_ 6th Ed. by Jesperson, Brady and Hyslop. © 2000-2012, pages 595-597

The graphic above illustrates mixed gases in the volume of a closed container. Work is done to compress the volume which increases the total pressure and

temperature of all the gas molecules in that volume, which in turn increases the absorption of each of those molecules in the liquid. In the open atmosphere, when a gas such as CO_2 is added, then the volume of the atmosphere increases but the total pressure and temperature of the atmosphere do not increase. Usually, when CO_2 is added, O_2 has been removed, so the volume change is negligible; but the ratio of the number of CO_2 molecules with respect to the O_2, N_2, H_2O and other atmospheric gas molecules changes. That is, the partial pressure of CO_2 increases relative to the other atmospheric gas molecules. Similar to Figure 13.11, when the partial pressure of CO_2 increases, then the rate of collision of CO_2 molecules with all surfaces increases relative to the other gas molecules since there are numerically more of them. The absorbance of CO_2 molecules into all liquid surfaces increases relative to the other gas molecules. And also absorbance of CO_2 molecules into liquid surfaces increases relative to the emission of CO_2 molecules from liquid surfaces. In the natural environment, absorption of gases into liquids surfaces and emission of gases from liquid surfaces are happening simultaneously and continuously. Note that the surface is dominantly the surface of sea water in the ocean, about 71% of earth's surface, but also the surface of lakes, rivers, and water in soil, water in leaf tissue, water in lung tissue, raindrops, and bubbles.

Existentially important for all life on earth, CO_2 is plant food, absolutely necessary for all green plants for their use in photosynthesis in their cells by sunlight to grow the carbohydrate structure and cells of the plant. The only way CO_2 enters plants is by absorption of CO_2 from air into water in the plant's tissues. Oxygen emitted to the air is a by-product of the plant's photosynthesis of CO_2. Not only are plants on land and in ocean feeding all animal life, but they are also providing oxygen for animals to breath. In other words, efforts by so-called environmentalists and proponents of Net Zero and Climate Crisis to reduce CO_2 are a planetary suicide pact. The ONLY way CO_2 gets into plants to feed them is by absorption of CO_2 from the air.

Henry's Law defines the ratio of (1) a gas absorbed into liquid surfaces versus (2) the same gas emitted from that surface. As previously discussed here, the ratio (or coefficient) of absorption to emission is an inverse function of the temperature of the surface interface between the liquid and the gas. In other words, cold surfaces absorb more gas than warm surfaces. This inverse function is true for all natural gases and liquids. Warm liquid surfaces emit more gas than cold liquid surfaces. The coefficient or ratio of absorption versus emission is known as the Henry's Law constant k_H which is dependent on temperature. A k_H is not a function of nor dependent on the source of the gas nor on the amount of the gas. A k_H is an intensive property of matter, like a boiling point or specific heat.

There is a unique k_H for each combination of a liquid solvent and a gas solute. Thus k_H for seawater and oxygen is different than k_H for seawater and CO_2. But absorption of both oxygen and carbon dioxide increase as the temperature of the surface decreases, and vice-versa. Warmer ocean surface causes larger numbers of CO_2 gas molecules (and all other gas molecules) to be emitted to air compared to the number of CO_2 gas molecules (and all other gas molecules) colliding with ocean surface and being absorbed into the ocean water. Since the temperature of the ocean surface is changing continuously by various causes including day/night, clouds, seasons, air and ocean currents, convection, wind, waves, etc, no static equilibrium condition exists; Henry's Law defines dynamic equilibriums in the real world.

The probable reason for the slowly increasing trend in net global CO_2 concentration (e.g., the Keeling Curve) is not CO_2 emissions by humans burning fossil fuels but is instead the slowly increasing trend in sea surface temperature, as shown in the following graphic presented by Ole Humlum in his Dec 7, 2020 lecture to CLINTEL ICSF.
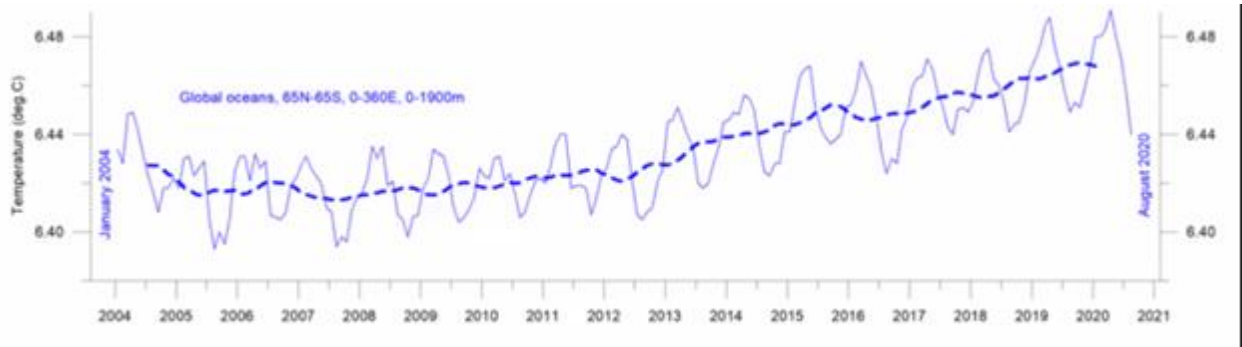
This short video illustrates the different relative solubilities of gases in water.

Using Henry's Law we can calculate the concentration of any known gas in any known liquid at any known temperature if we measure the concentration or the partial pressure of the gas above the liquid. The gas measurement in the gas matrix is much more accurate and reproducible than the gas measurement in the liquid matrix. For example, we can calculate the concentration of nitrogen gas (N_2) in water at 25 degrees C. We measure or look up in a textbook that N_2 is 78.08% of air by volume. Thus the partial pressure of nitrogen in air by volume is $0.7808 = pN_2$. We also find in a textbook or online software that the Henry's Law constant for N_2 in water is 6.48×10^{-4}. The Henry's Law equation arranged for partial pressure is at 25 C,

$k_H = cN_{2aqueous} / pN_2$
where k_H is the Henry's Law constant for N_2 gas solute in water solvent = 6.48 X

- 4 -

10^{-4}

$cN_{2aqueous}$ is the concentration of the N_2 gas which is dissolved in the water, which is our unknown in this example.

pN2 is the partial pressure on N_2 gas in the air above the water = 0.7808
this simple algebra:

$cN_{2aqueous} = k_H \times pN_2 = 6.48 \times 10^{-4} \times 0.7808$

Thus $cN_{2aqueous}$ (i.e., the concentration of N_2 gas in water at 25 C) = 5.06 X 10^{-4} moles of N_2 gas per liter of water.

Conveniently, there are several different derivations of the Henry's Law equation for different purposes. The U.S. National Oceanographic and Atmospheric Administration (NOAA) lab and Scripps Oceanographic Institute (Scripps) co-manage a set of laboratories around the globe called the Global Monitoring Laboratories (GML) which measure net CO_2 in air as well as other gases in air. The NOAA-Scripps GML lab at Mauna Loa, Hawaii is generally accepted as the defacto gold standard for comparison to other labs. The NOAA-Scripps GML lab at Mauna Loa has for many decades measured CO_2 in air by molar mass in dried air rather than by volume; the GML labs report CO_2 as micromoles of CO_2 per moles of air, which is equivalent to parts per million (ppm), not ppmv. Thus the dimensionless version of k_H is most convenient for atmospheric gases. The version of the Henry's Law equation for molar mass for a given temperature of the liquid surface is:

$k_H = c_{aq} / c_g ve$

where:

c_{aq} = concentration by molar mass of the gas dissolved in the liquid

c_g = concentration by molar mass of the gas in air above the liquid

$c_{aq} / c_g = c_{aq}$ divided by c_g

the resulting k_H is dimensionless or unitless since the units are cancelled out in the division arithmetic

Now we can look up the dimensionless version of k_H for CO_2 in water at a given temperature of ocean surface and use this along with the Mauna Loa-measured net CO_2 in ppm to calculate the CO_2 in water. Thus units in our calculation formula match units for gold standard CO_2 measurements, avoiding the difficult conversion of ppmv volume units of air which contain continuously varying amounts of water vapor to the gold standard measured units of ppm molar mass in dry air reported by the GML.

It is important to point out that these labs do not measure human CO_2 emissions, nor could they do so with acceptable accuracy and reproducibility. These labs measure net CO_2, which is total CO_2 emissions by all sources (natural and human) minus total CO_2 absorptions by all sinks (natural and human). This is

rarely pointed out to the public, which, due to this omission, the general public is allowed to erroneously believe that the famous Keeling Curve (example below) shows the growth in human CO_2 emissions.

Dimensionless k_H values can be found here Sander (2023): https://acp.copernicus.org/articles/23/10901/2023/ or in the attached pdf Sander (1999). Sander presents theoretical background, tabular constants, conversion factors between the various version of k_H and the derivation of Henry's Law for its temperature dependence, as well as copious references.

It is worthwhile to mention that these results are consistent with peer reviewed published results of well executed experiments. Here is an abstract of one example, work reviewed by Charles Keeling founder of the GML lab at Mauna Loa (pdf).

"Associations between the sea-surface temperature (SST) in the eastern equatorial Pacific (0°-10°s, 1800-80°W) and changes in atmospheric CO_2 concentration have been examined. The CO_2 records at Mauna Loa and the South Pole of the Scripps Institution of Oceanography, and the shorter records of the Geophysical Monitoring for Climatic Change program at Barrow, Samoa, the South Pole and Mauna Loa, were used after the annual cycles and the growth due to fossil fuel emissions had been removed. We find that warmer than average SST precedes above-average increases in CO_2 by about one season at Mauna Loa and two seasons at the South Pole. The shorter records at Samoa and Barrow support longer lags - 2 to 3 seasons at Samoa and 3 to 5 seasons at Barrow. The correlations and their lags change with time, however, there being periods of relatively high correlation associated with El Niiio events and periods of lower correlation when El Niiio is not present. Furthermore, there is a seasonal preference for these high correlations. At Mauna Loa, the change of CO_2 from (NH) fall to spring is better correlated with antecedent SST than the changes from spring to fall. At the South Pole, a similar pattern is found with a one-season shift."

William P. Elliott & James K. Angell (1987) On the relation between atmospheric CO_2 and equatorial sea-surface temperature, Tellus B: Chemical and Physical Meteorology, 39:1-2, 171-183, DOI: 10.3402/tellusb.v39i1-2.15335 To link to this article: https://doi.org/10.3402/tellusb.v39i1-2.15335

The effect of pressure on the solubility of a gas can also be explained by Le Châtelier's principle. In this case, the disturbance is an increase in the pressure of the gas above the solution. How could the system counteract the pressure

increase? The answer is: by having more gas dissolve in the solution. In this way, the pressure of the gas is reduced and the concentration of the gas in the solution is increased. In other words, increasing the pressure of the gas will cause the gas to become more soluble.

Figure 13.12 shows how the solubility in water of oxygen and nitrogen vary with pressure. The straight lines on the graph indicate that the concentration of the gas is directly proportional to its pressure above the solution. This is expressed quantitatively by **Henry's law**, which states that *the concentration of a gas in a liquid at any given temperature is directly proportional to the partial pressure of the gas over the solution.*

$C_{gas} = k_H P_{gas}$ **(T is constant)   (13.4)**

where C_{gas} is the concentration of the gas and Pgas is the partial pressure of the gas above the solution. The proportionality constant, k_H, called the Henry's law constant, is unique to each gas. The equation is an approximation that works best at low concentrations and pressures and for gases that do not react with the solvent.
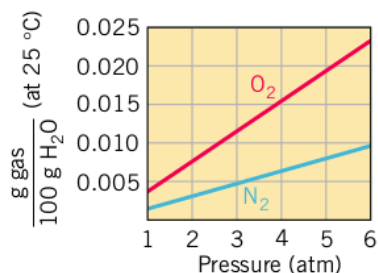
Figure 13.12 | **Solubility in water versus pressure for two gases.** The amount of gas that dissolves increases as the pressure is raised.

An alternate (and commonly used) form of Henry's law is

$$\frac{C_1}{P_1} = \frac{C_2}{P_2}$$

(13.15)

where the subscripts 1 and 2 refer to initial and final conditions, respectively. By taking the ratio, the Henry's law constant cancels.

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Seventy one percent of the Earth's surface is water-covered. The oceans hold about 96.5 percent of all Earth's water. Water also exists in the air as water vapor, in rivers, lakes, icecaps, and glaciers, in the ground as soil moisture, aquifers, and in all living organisms.

There are winds and ocean currents and the mass transfer coefficients between the atmosphere and oceans are extremely varied, numerus and chaotic. Ocean cycles go to great depths and have cycle periods of hundreds of years. The surface of the sea may be calm, wavy, or frothy with bubbles forming foam and sprays of droplets, and even ice. All of these impact the mass transfer coefficients. But all these are independent from the partial pressure differential of CO_2 between the atmosphere and the biosphere's many sectors which is controlled solely by Henry's Law and its variables; principally the water surface temperature at any air water surface boundary.

Henry's Law Controls Atmospheric CO_2 Level

1. Henry's Law does not apply to the chemical reactions and chemical reaction products which begin with and are subsequent to the ionization of CO_2 gas with water ions. Henry's Law does not apply to H_2CO_3, CO_3^{-2}, HCO_3 and the hundreds of other carbonate reactions that occur in seawater and biosphere which occur subsequent to the ionization of CO_2 gas in water. The Henry's Law constant is a physical partition ratio of a specific gas (i.e., the solute gas) dissolved in a specific liquid (i.e., the liquid solvent) in continuous contact with the same solute gas immediately above the same liquid surface; Henry's Law defines a physical phase-state partition, like a melting point or boiling point. Henry's Law does not define chemical reactions, but defines the ratio of a change of phase of a gas in a gas matrix versus the same gas in a liquid matrix.

2. Henry Law applies to all natural gases and liquids. For our interest here, Henry's Law applies to the approximately 1% or less of CO_2 gas which diffused into and is absorbed into water, and that ~1% is not ionized, is electrically neutral, uncharged. It is "approximately" 1% because the exact percentage depends on the temperature of the water. Temporarily local conditions in the water including alkalinity, pH, salinity, temporarily change CO_2 gas concentration in the local conditions by changing the equilibrium of the several carbonate chemical reactions, similar to adding salt to boiling water to raise the temperature of the water.

3. Henry's Law only applies to solute gases which are in minor concentrations relative to the gas matrix and relative to the liquid matrix. For avoidance of doubt, 400 ppm or 5000 ppm CO_2 gas in air or water are minor concentrations. A solute is defined as a minor component dissolved in a liquid.

4. The Henry's Law equilibrium is always a dynamic equilibrium. It is never a static equilibrium as an equilibrium is commonly considered because the temperature of natural waters such as the ocean, or a bubble, or a raindrop, are never static, thus the Henry's law ratio is never static. There is no average temperature of earth's surface, nor ocean surface, nor atmosphere, nor column of ocean water, these are calculations not measurable within the uncertainty required by science, thus there is no average Henry's Law constant for a specific combination of liquid and gas. There is no global Henry's Law constant for CO_2 and ocean. The Henry's Law constant in polar latitudes is different from tropical latitudes due to different sea surface temperatures.

5. Le Chatelier's Principle is the basis for all processes of absorption and emission of gases into and out of all liquids. A liquid-gas system which is not in equilibrium tends to approach equilibrium. Thus, if the liquid is not saturated with a gas under the existing conditions, then the liquid tends to absorb a gas at a higher rate than it emits a gas. Thus the Henry's Law coefficient or constant describes the limiting condition, a condition which is always being approached but never achieved because CO_2 gas reacts (hydrates) with water ions and those ions subsequently react with other ions and molecules in the water matrix. The result is CO_2 is being continuously but converted to various forms of carbonate, dominantly one of the forms of calcium carbonate since calcium ions are about 4 times as abundant as the bicarbonate, carbonate and carbonic acid combined in the well mix layers of ocean, and then slowly precipitated as solid incorporated in stone or structure of coral, sea shells, or sea creatures. With about 4 times more calcium ions as carbonate ions, ocean is only saturated with CO_2 gas in temporary and local conditions and when those conditions subside to absorption of CO_2 gas will begin again to approach equilibrium. Unless some catastrophic geological or astronomic event occurs that overcomes the multiple chemical buffering systems in ocean to dramatically alter pH, alkalinity, or salinity, then it ocean will be an infinite and perpetual sink for absorbing all CO_2 up to the limit of the Henry's Law ratio.

6. Henry's Law is an intensive property of matter, like a boiling point, a melting point or a specific heat. The defining characteristic of an intensive property of matter is: the amount of matter does not change the constant. Henry's Law is an Arrhenius Constant, which means the constant varies

- 9 -

with temperature. The amount of CO_2 added to the atmosphere by any source natural or human, and the amount of CO_2 absorbed into any sink natural or human, does not change the Henry Law constant at a given temperature. Henry's constants are determined by the specific gas solute, the specific liquid solvent and the specific temperature at the gas/liquid interface. Henry's Law is valid for all known solute gas and solvent liquid combinations, not only CO_2 gas and seawater.

7. Henry's Law constants are ratios of the molar mass of the unreacted solute gas which is diffused into the liquid divided by the molar mass of the unreacted solute gas in the air immediately above the liquid/gas interface surface. Henry's Law constants are intensive properties of matter because the diffusion rate of any solute gas into any liquid solvent is inversely proportional to the square root of the molecular weight of the solute gas, and the molecular weight of a gas is a constant; this is Graham's Law. Solubilizing a gas follows diffusion of the gas into the surface.

8. Henry's Law constants are a function of the temperature of the interface surface between the gas and the liquid, wherever that surface exists. The absorption rate (or solubility) of all gases in all liquids is inversely proportional to the temperature of the liquid surface. Emission of the gas from the liquid surface is directly proportional to the temperature of the liquid surface. The surface interface may be as vast as the surface of the ocean, i.e. 71% of earth's surface, or as small as the surface of a small bubble of gas released deep in the ocean, or the surface of a raindrop condensing in a cloud. All of this paragraph applies to all atmospheric gases, not only CO_2.

9. Unfortunately, many textbooks and science papers merge aqueous CO_2 gas with carbonic acid and this causes misunderstanding and error regarding Henry's Law. Henry's Law does not apply to carbonic acid, but does apply to aqueous CO_2 gas. In these unfortunate documents, the two combined chemical entities are usually given a hypothetical nomenclature like CO_2^* or similar, an entity which does not exist. This is done for hypothetical and theoretical considerations in a supposed static equilibrium which also does not exist; these hypotheticals result in confusion and error regarding Henry's Law. These hypothetical expressions are used because the CO_2 hydration reaction is almost instant, and the reverse reaction is also nearly instant. The forward and reverse reactions occur continuously and simultaneously due to continuously variable temperature changes in the surface water thin layer, changes in alkalinity, pH, salinity, changes partial pressure of the CO_2 gas in the water surface thin layer, as well as changes in the gas thin layer immediately above the water surface.

CO$_2$ gas in air (and all other gases in air) are continuously and simultaneously colliding with the surfaces such as ocean at continuously varying collision rates due to variations in air temperature/pressure and variations in CO$_2$ partial pressure. Similarly, CO$_2$ effusion from ocean surface occurs continuously and simultaneously with diffusion into the surface; but the rate of emission and the rate of absorption are not parallel due to the wide difference in density between the liquid matrix and the air matrix and the intermolecular and interionic forces in the liquid thin layer which are negligible or do not exist in the air thin layer matrix above the liquid surface. Thus, effusion into air is faster than diffusion into water. (Description of the chemistry and physics of the water thin layer and air thin layer are interesting and important, involving virial forces between the molecules and ions, van der Wals force, surface tension, but these are beyond the topic here.)

The rapid and reversible CO$_2$ hydration reaction means the products, reactants and activation energies of the CO$_2$ hydration reaction are difficult or impossible to measure with sufficient accuracy or precision. In practice, the molar mass concentration of the CO$_2$ gas in the head space above the liquid surface is quantified by gas chromatography or gas chromatography mass spectrometry and then the molar mass of the CO$_2$ gas in the liquid are calculated by Henry's Law. Accurate and precise sampling of the reactant CO$_2$ gas and the product carbonic acid in the hydration reaction is extremely difficult if not impossible. For example, Keeling et al and many others have sampled ocean water and air for CO$_2$ gas. But, sampling from moving vessels e.g., the many voyages of Charles Keeling and many others, or sampling in wind or ocean currents, or wave-disturbed surfaces, causes changes in CO$_2$ partial pressure (and other variables) resulting in measurement errors. The rapidly reversible CO$_2$ chemical hydration reaction occurs in all layers of the ocean and the CO$_2$ physical phase state reaction occurs at all layers of the ocean and in the troposphere.

10.   Agitation of air or water increases their temperature as well as increases the surface area of the interface and this changes the net flux rate of the gas. The net flux of a gas through a surface interface is a function of the surface area of the gas/liquid interface, and a function of the thickness of that interface layer, and a function of the gradient of the gas in the interface layer, and a function of the Graham's Law diffusion constant for the solute gas. Net flux is the vector directional residual difference between the molar mass of all solute gas emissions minus the molar mass of all solute gas absorptions passing through a known amount of surface area and known surface thickness in a known time period; for example gigatons of CO$_2$ gas emitted into air per square mile of ocean surface per year. Net flux is directional (either absorption or emission.) Net

flux is defined by Fick's 1st Law. The CO_2 concentration measured at NOAA Mauna Loa is a generally accepted defacto standard for the average net global CO_2 concentration. The slope of that Mauna Loa concentration record with respect to time (often called the Keeling Curve) is the slope of the net flux of CO_2 with respect of time, which is dominantly (~ 71%) the record of Fick's 1st law for net flux CO_2 gas and ocean. The Mauna Loa lab (and most NOAA and similar labs) measures by molar mass the net residual difference of CO_2 gas emitted from all sources of CO_2 gas natural and human minus all CO_2 gas sinks natural and human; these labs do not and could not measure global human CO_2 emissions, nor net human CO_2 emissions nor net human CO_2 flux.

The much higher density of water compared to the density of air causes much higher CO_2 gas concentration in ocean water matrix compared to CO_2 gas concentration in air. This occurs at all depths of ocean, regardless of mixing. Geology texts calculate the ratio of CO_2 gas in ocean versus CO_2 gas in air at about 50:1, which is a very broad average. The ratio varies with temperature and altitude (air pressure/density) and ocean depth (water pressure/density). Density of water increases rapidly with depth while density of air decreases with altitude but less rapidly. There are systemic processes as well as chaotic processes of mixing in both atmosphere and ocean. There is layering within both atmosphere and ocean and different physical and chemical reactions occur in the different layers. The less-well mixed deep ocean layers contain much higher molar concentration of CO_2 gas than the well-mixed medium ocean layer. The more well mixed surface ocean layer (which is usually but not always warmer than the layers below) contains lower concentration than the ocean layers beneath it. Theoretically at the ideal limit, at the air/ocean surface interface, in the ocean thin film layer of a few molecules thickness, in calm flat seas with no water current and no wind, the Henry Law constant for a given ocean surface temperature determines the molar concentration of CO_2 in the water surface divided by the molar concentration of the CO_2 in the air thin layer above the surface; practically, this ideal theoretical condition does not exist except in transition.

The hypothetical equilibrium condition for Henry's Law means that the ratio of the number of gas molecules of a specific gas being absorbed by a liquid surface versus the number of molecules of the same gas being emitted from that liquid surface is a constant for the given temperature of the surface. Unlike total pressure of mixed gases where at equilibrium the amount of total gas emitted equals amount of total gas absorbed, instead, Henry's Law applies to partial pressure of a single specific gas, wherein, the ratio absorption vs emission of the single gas is the Henry's Law partition ratio, or coefficient. Absorption and

emission are occurring simultaneously, but not at the same rate. The absorption rate of a specific gas like CO_2 into water surface can be increasing while simultaneously the rate of emission of CO_2 from the nearby water surface can also be increasing; the conditions causing these two opposing perturbations to the Henry's Law partition ratio for CO_2 gas and water are different in the gas matrix and the liquid matrix.

When CO_2 is added to air by burning fossil fuels, other sources of CO_2 are naturally reduced and/or sinks are naturally increased so that the Henry's Law ratio is maintained for the surface local temperature. It is a dynamic equilibrium and the control knob for the gas concentration, if you will, is the Henry's Law ratio at the local surface temperature. CO_2 is not accumulating in the atmosphere as hundreds of scientists and millions of dollars spent on annual carbon budgets attempt to persuade. CO_2 has been increasing slowly in recent years because sea surface temperatures (SST) have been increasing in recent years. If and when SSTs begin decreasing, the CO_2 concentration in air will also begin declining, though this decline is slow due to the enormous (orders of magnitude) higher heat capacity of ocean compared to atmosphere. For now, slowly warming SST and rising CO_2 are both good for life.

Warming and cooling of ocean are very slow processes requiring centuries or millennia due to the enormous heat capacity of the ocean. The causes of warming and cooling are beyond the scope of this email except to point out firmly that they are definitely not caused by human-produced CO_2;this statement does not require refutation or denial of the so-called "greenhouse gas" theory, radiative emission theory, carbon budgeting, feedbacks, etc.

The Henry's Law coefficient is usually defined as $k_H = c_a/p_g$

Where:

- k_H refers to standard conditions, T = temperature = 298.15 K = 25 degrees C, and total pressure is 1 atm.

- c_a is the concentration of the unreacted solute gas in theliquid phase

- p_g is the partial pressure of the same solute gas in the gas phase incontinuouscontact with the surface of the liquid phase.

This version of Henry's Law above requires calculations and measurements in volume for p_g.

One of the common problems encountered with Henry's Law is its dependence on temperature. k_H is a constant (or coefficient, or ratio) that varies with temperature. This is not a simple matter. For example, one of the teachers for

chromatography classes for the American Chemical Society, who was one of the founding fathers of gas chromatography, published errors of Henry's Law constants derived for temperature ranges; he was not alone. No doubt this author's own writings on his personal web blog have errors too. Derivation of Henry's law constants as a function of temperature is based on solution of the Clapeyron or Van Hoff equations formulated for water-gas equilibrium. Great care is required with the units.

$$d\ln k_H/dT = \Delta H_{dis}/R_g T^2$$

Where:

- ΔH_{dis} is the enthalpy (or heat) of dissolution of the gas solute in water
- R_g is the gas constant
- T is temperature in Kelvin.

Henry's Law constant for CO_2 gas and water solution. (as given in reference 5 below)

$k_H(T) = k°_H \exp(d(\ln(k_H))/d(1/T) ((1/T) − 1/(298.15 \text{ K})))$
$k°_H$ = Henry's law constant for solubility in water at 298.15 K (mol/(kg*bar))
$d(\ln(k_H))/d(1/T)$ = Temperature dependence constant (K)

For our purposes studying CO_2, atmospheric gases and Henry's Law, a different derivation of Henry's Law is much more convenient. Sander provides this derivation also: the Henry's Law coefficient is derived in its dimensionless (or unitless) form as the quotient (or ratio) of the molar concentration of the unreacted solute gas dissolved in the liquid phase matrix divided by the molar concentration of the same solute gas in the gas phase matrix. It is dimensionless since the units drop out when dividing molar mass by molar mass. But, the temperature derivation is still difficult. Today fortunately we look up Henry's coefficients in reference books or by online software and then carefully verify the units. There is a different k_H for each gas and liquid combination and each temperature.

Henry's Law expert Rolf Sander provides further expansion of various derivations in section 4.2 of the IUPAC Recommendations 2021 paper with other detail on the other forms of Henry's law for various purposes here: https://www.degruyter.com/document/doi/10.1515/pac-2020-0302/html and references (4) and (5) below.

These two equations for Henry's law, the partial pressure version above and the dimensionless version below, are related through the ideal gas law, where k_H = k_H x RT.

The dimensionless version:

$k_H = c_a/c_g$

Where:

- k_H = the Henry'sLaw coefficient
- c_a = concentration of the gas in moles in the aqueous phase
- and c_g is concentration of the same gas in the gas phase above the liquid/gas surface.

Generally, the dimensionless version is most convenient because the defacto NOAA-Scripps Mauna Loa "gold standard" CO_2 data has been diligently measured and reported for many decades as micromoles of CO_2 per mole of dry air. Micromoles of CO_2 per mole of dry air is identical to ppm, parts per million by mass. This is a mass measurement, not a volume measurement, which is far more practical, precise and accurate for measuring trends in atmospheric gases since air always contains the gas water vapor, the quantity of water vapor in air is highly variable which causes the sample volume to be highly variable. Water vapor concentration in air is normally 10 to 100 times higher than the trace gases like CO_2, methane (CH_4), etc. Also, water vapor and CO_2 have overlapping wavelengths of infrared light used in measurement instrumentation. These are reasons NOAA-Scripps dries their air samples (by freezing) and measures by mass instead of volume, i.e., micromoles of CO_2 per moles of dry air which equals ppm.

Important note: ppm is not the same as ppmv. This is a common and large source of error in measuring net CO_2 trends compared to the minor annual change in net global CO_2 concentration.
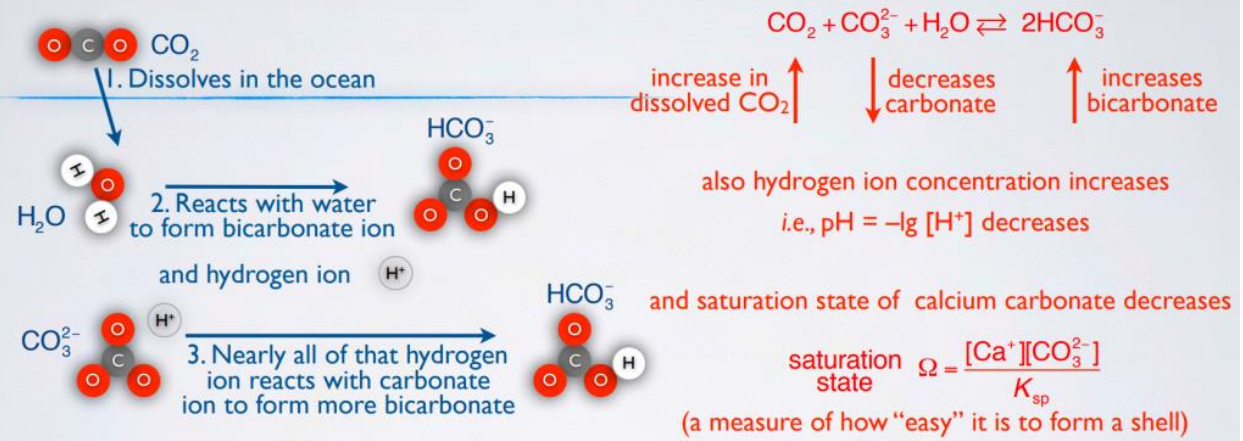
Henry law coefficients are available online, having been measured thousands of times for thousands of combinations temperatures, liquid solvents and gas solutes. The concentration of CO_2 in water is easily calculated from the gas concentration and the Henry's coefficient, but the CO_2 and H_2CO_3 (carbonic acid) concentrations are difficult or impossible to measure in water with acceptable accuracy and precision because sampling procedures affect the hydration reaction.

The gas-water surface interface can be the surface of a bubble at 3000 meters depth in ocean, or the surface of a raindrop in a cloud at 3000 meters altitude, lung tissue, leaf tissue, or dominantly the surface of the ocean.
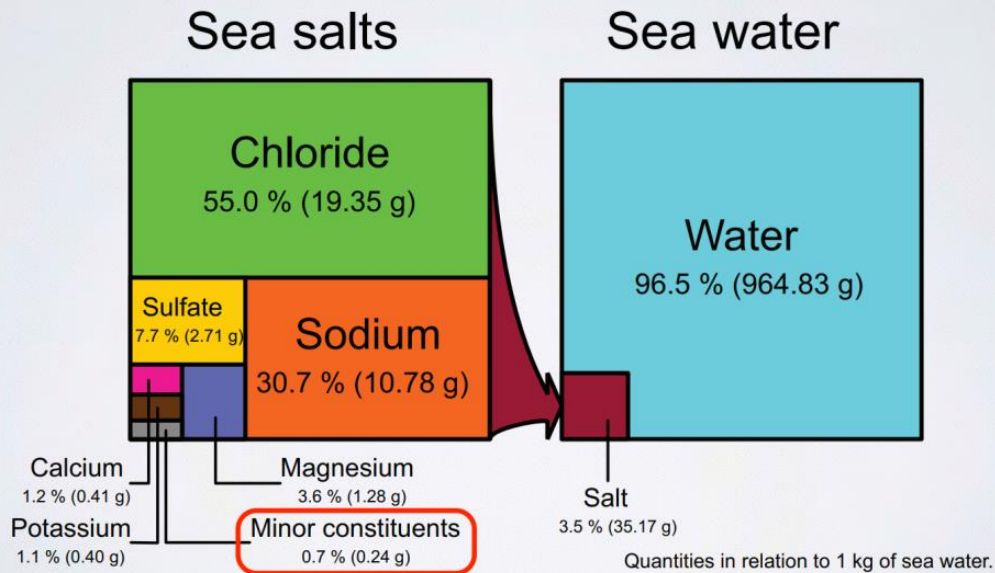
In a mixture of gases, the flux of one gas back and forth across the surface does not affect the flux of a different gas until concentrations are very high. This was demonstrated by Adolph Fick, a physiologist, who studied air gas fluxes in lung tissues, a contemporary of William Henry, Thomas Graham, and John Dalton.

In nearly pure water like raindrops, the aqueous CO_2 gas concentration is high and the H_2CO_3 (carbonic acid) concentration is high relative to the HCO_3^- (bicarbonate) concentration. Thus raindrops are measured slightly acid. Carbonic acid is a weak acid. But those raindrops also absorb other gases of nitrogen and sulfur (for example near an urban area or a refinery) which create strong acids in water. In contrast, in seawater HCO_3^- is the dominant species because there are very many more ionic species (sodium, calcium, etc.) dissolved in seawater which easily pull the first hydrogen ion away from the H_2CO_3. The concentration of calcium ion by itself is about 4 times as abundant in seawater surface as the combined concentrations of unreacted CO_2 gas, bicarbonate ion, carbonate ion, and carbonic acid. The first dissociation constant for pulling away the first hydrogen atom from H_2CO_2 leaving HCO_3^- is very small and the reaction is nearly instant. So, dependent on the seawater conditions, HCO_3^- can be both a reaction product from the CO_2 gas hydration reaction and also a reaction product from the dissociation reaction of H_2CO_3.

EFFECT OF ADDING CO_2 TO SEA WATER

$$CO_2 + CO_3^{2-} + H_2O \rightleftharpoons 2HCO_3^-$$

- CO₂ 1. Dissolves in the ocean
- increase in dissolved CO_2 ↑
- decreases carbonate ↓
- increases bicarbonate ↑

HCO_3^-

H_2O 2. Reacts with water to form bicarbonate ion

also hydrogen ion concentration increases
i.e., pH = –lg [H⁺] decreases

and hydrogen ion (H⁺)

HCO_3^- and saturation state of calcium carbonate decreases

CO_3^{2-} 3. Nearly all of that hydrogen ion reacts with carbonate ion to form more bicarbonate

saturation state $\Omega = \dfrac{[Ca^+][CO_3^{2-}]}{K_{sp}}$

(a measure of how "easy" it is to form a shell)

COMPOSITION OF SEA WATER ($S = 35$)

Sea salts

- Chloride 55.0 % (19.35 g)
- Sulfate 7.7 % (2.71 g)
- Sodium 30.7 % (10.78 g)
- Calcium 1.2 % (0.41 g)
- Magnesium 3.6 % (1.28 g)
- Potassium 1.1 % (0.40 g)
- Minor constituents 0.7 % (0.24 g)

Sea water

- Water 96.5 % (964.83 g)
- Salt 3.5 % (35.17 g)

Quantities in relation to 1 kg of sea water.

Graphics above from Andrew G. Dickson, Scripps Institution of Oceanography, UC San Diego, INTRODUCTION TO CO_2 CHEMISTRY IN SEA WATER.(6)

There are many simultaneous phenomena occurring at these air/liquid surfaces. I have not touched on most of them. The most important quantitatively is the physical phase state reaction, wherein the change in partial pressure of the solute gas within the gas matrix causes a proportional change in the solubility of that unreacted solute gas in the liquid phase. When humans or any other source add CO_2 to air, then the solubility of CO_2 gas in water increases proportionally to absorb that CO_2 gas. Double the partial pressure of CO_2, then solubility of CO_2 in water doubles. And vice versa.

The Henry's Law ratio is a variable of surface temperature, not a variable of the amount of gas present, and not a variable of the source of the gas; it applies to all gas solutes in low concentrations with respect to the liquid solvents with which they are in continuous contact. The ratio does not apply to any portion of the gas solute which has reacted with the liquid solvent itself or has reacted with any component dissolved in the liquid solvent. Residence time, or half-life, or residual fraction, of the CO_2 in air are not variables in the Henry Law phase-state equilibrium and play no role in net global CO_2 concentration.

Next in importance is to understand that the CO_2 hydration reaction ($CO_2 + H_2O$ $<->H_2CO_3$) is nearly instantly reversible, for example by a very minor increase in water temperature, or agitation of the water, or change in other variables. Then the first dissociation constant K_1, which is dissociation on one hydrogen away from H_2CO_3, this K_1 is small, yielding HCO_3^{2-}. The subsequent K_2 dissociation reaction to CO_3^{2-} is relatively larger. Both reactions are nearly instantly reversible. But the hydration reaction $CO_2 + H_2O <-> H_2CO_3$ is so fast it is unmeasurable. Sampling changes the measurement. Unfortunately many textbooks merge unreacted aqueous CO_2 gas and H_2CO_2 into a single hypothetical entity, which has apparently led to misunderstanding.

There is a highly abundant (>90%) reservoir of these readily available carbonate ions in seawater surface thin layer and well mixed layer which are not unreacted aqueous CO_2 gas but which are very rapidly convertible to unreacted aqueous CO_2 gas when the unreacted aqueous CO_2 gas in seawater is depleted. And vice versa. We have shown this in Bromley & Tamarkin (2022). Depletion of CO_2 in air as well as CO_2 in water occurs by many different processes, and addition of CO_2 to air and water occurs by many different processes.   For example, outgassing of CO_2 from water to air occurs to rebalance to Henry's Law coefficient when CO_2 concentration in air is being depleted by photosynthesis of land plants or by surface winds; conversely when aquatic plants like plankton bloom in ocean and absorb aqueous CO_2 gas for their photosynthesis, then CO_2 gas will be absorbed into water from air at higher ratio than is being emitted from water to air until the Henry's Law coefficient is achieved for the water surface temperature.   These opposing processes can and do occur simultaneously, which is probably a reason climatologist rarely if ever attempt to model Henry's Law.

To summarize so far, when the approximately 1% of aqueous CO_2 gas is either increased or decreased by any amount, due to any source or sink, this perturbation causes a recovery (following le Chatelier's Principle) to rapidly return to that 1% by the using ocean's chemistry systems, and there is an abundant reservoir of ionic carbonates in ocean water to achieve that recovery. In other words, the amount of CO_2 emitted by humans replaces naturally emitted

CO$_2$ in the phase-state equilibrium, rather than accumulating in the atmosphere in addition to naturally occurring CO$_2$. There is no CO$_2$ accumulation in atmosphere. The ~1% can be perturbed in both directions by changes in temperature, salinity, pH, alkalinity, and by changes in partial pressure of the CO$_2$ in the water or in the air. Adsorption and emission of CO$_2$ are simultaneous and continuous in both directions at normal earth temperatures since CO$_2$ molecules are continuously colliding with the surface and being emitted from the surface. The rate of absorption vs emission is the Henry's Law coefficient for the local water temperature.

It is very important to mention that CO$_2$ gas molecules and the three forms of carbonate ions (H$_2$CO$_3$, HCO$_3^{2-}$, CO$_3^{2-}$) do not need to migrate in water more than molecular distances to react with each other. Scientific publications which are adopted into the anthropogenic global warming (AGW) orthodoxy and climate models, for example work by (1) Bert Bolin (1960) first administrator of UN IPCC, and (2) Broecker and Peng (1974), and others, considered the thickness of the water thin layer and limited their calculus of aqueous CO$_2$ migration to thickness of the water matrix. They define the chemical pathways that convert CO$_2$ to HCO$_3^-$ and vice versa as "chemical enhancement." They calculate based on the thickness of the thin layer and migration time of the carbon species in the ocean matrix, however they ignore an equally critical variable which is the surface area of the gas – liquid interface, omitting more than 100 million square miles of air-water surface interface. This appears to be a major mistake in the AGW orthodoxy and modeling. Keep in mind that in these years of early papers seminal to IPCC orthodoxy, CO$_2$ emissions were said to cause global cooling; I speculate they were focused on their modeling methods rather than empirical observations.

For example, "The rate limiting step for removal of anthropogenic CO$_2$ from the air is vertical mixing within the sea rather than transfer across the air-sea interface."(2) This statement conflicts with Fick's 1st Law of net flux of gases.

Why did Bolin and Broecker & Pang (for example) consider only thickness of the ocean thin layer and not the huge square surface area of ocean? It is a puzzle. The 3 carbonate ionic species are distributed throughout the area of the thin layer as well as the well mixed layer beneath it and they surround the uncharged aqueous CO$_2$ gas molecules in the thin layer and well mixed layer in a ratio of over 9:1. If the uncharged aqueous CO$_2$ gas molecule is removed from the liquid matrix by either outgassing or by absorption into aquatic plants, then the carbonate reactions reverse and produce more uncharged aqueous CO$_2$ gas molecules. And vice versa. And when the carbonate ion CO$_3^{2-}$ reacts with for example a very abundant ion such as calcium Ca^{2+} and solidifies, then the carbonate ion in water is thus reduced one for one. CO$_3^{2-}$ +Ca^{2+} = CaCO$_3$. Then

as a consequence of this reaction (which occurs in warmer water near the surface, and reverses in colder deeper, higher pressure water), the prior carbonate and the hydration reactions are forced to re-equilibrate by absorbing more CO_2 from air. Thus, there is a perpetual CO_2 gas sink rate absorbing CO_2 from air even while warming SST is slowly increasing outgassing CO_2. These simultaneously opposed dynamic processes are mediated by Henry's Law and the carbonate reactions.

Attached is a pdf (reference 3) which documents one of several gas chromatographic (GC) methods to quantify Henry's Law coefficients. To use this method for CO_2, since CO_2 does not burn in the flame ionization detector (FID) flame, instead the effluent from GC column is passed first over a rubidium catalyst which stoichiometrically converts the CO_2 to CH_4, and then the effluent is directed onward to the FID where the CH_4 is ionized and quantified. Alternatively, the FID can be replaced by a mass spectrometer and no catalyst is needed. I am pointing out that there is no mystery in Henry's Law, there are many of these methods well documented by theory and experiment, but AGW proponents either ignore it or fail to understand it or both.

On the Exchange of Carbon Dioxide Between the Atmosphere and the Sea (PDF)
Gas Exchange Between Air and Sea (PDF)
Introduction to CO_2 Chemistry in Sea Water (PDF)
A Laboratory Experiment To Measure Henry's Law Constants of Volatile Organic Compounds with a Bubble Column and a Gas Chromatography Flame Ionization Detector (GC-FID) (PDF)

Conclusion

Henry's Law describes the ratio between two gas concentrations:
1. The concentration of a specific gas (e.g., CO_2) dissolved in a liquid phase, (e.g., ocean water), versus… 2. The concentration of the same gas in the gas phase which is in continuous contact with the liquid phase… (e.g., CO_2 in air above ocean water.)
• where the ratio changes based on temperature of the surface interface between the gas and liquid phases
• where the ratio does not change based on the amount of the gas present,
• where the ratio changes based on the identities of the gas and the liquid

A Henry's Law constant is a ratio which describes the net amount of a gas in atmosphere versus that same gas in ocean water in contact with the atmosphere. But more generally, it describes all gases in contact with all liquids. Henry's Law is not a human invention, hypothesis or theory, but rather

carefully documented observations of nature. The primary gases in the atmosphere are nitrogen (78.084%,) oxygen (20.947%,) and argon (0.934%,) in the driest of conditions. However, water vapor (H_2O) can compose as much as 4% of the atmosphere in damp conditions and is highly variable.

The total of all other gases make up less than 1% of atmosphere and are called trace gases. These trace gases include carbon dioxide, ozone, methane, various oxides of nitrogen, neon, helium, hydrogen and other rare gases. They are called trace gases because they exist in small amounts. For example, the combined sum of natural and human-produced carbon dioxide is only 0.04% to 0.05% of the total atmospheric gases.

Carbon dioxide (CO_2) is both produced and used by many natural and human processes. Plants, animals, and inorganic chemical reactions use CO_2 from air, water, soil and rock and also return CO_2 in various chemical forms to the environment as bones and cellular structures of living creatures, then later in deposits such as shells, corals, and sedimentary rocks. The net result is CO_2 gas is being continuously removed from the environment for thousands or millions of years, and replaced by burning fossil fuels, cement production, respiration, volcanoes and tectonics, and these enormous processes are continuously mediated by Henry's Law and chemical balancing of the giant dissolved carbon reservoir in the ocean and CO_2 emitted.

The amount of CO_2 man introduces into the atmosphere by the combustion of carbon-based fuels is inconsequential, easily absorbed by the environment. Man could reduce his use of hydrocarbon fuels by 100% or increase them by 500% and at the end of the day 0% change in net atmospheric CO_2 concentration will be the result. This natural result occurs because any increase in any atmospheric gas concentration is offset by a proportional increase in absorption of that gas into nearby liquids. If CO_2 increases by 100% in a local area, then 100% more CO_2 will be dissolved into water in the local area. If CO_2 emission doubles, then water which is in contact with that CO_2 absorbs that increase and returns the CO_2 concentration to the CO_2 water/air ratio for the local temperature, and this is true for all gases not only CO_2. For all gases, colder water absorbs more gas, warmer water emits more gas. Oxygen which is dissolved in water and absorbed by fish gills for their respiration, the CO_2 which is the necessary gas of life for all green plants and thus all life, as well as the oxygen which is exchanged with CO_2 in the lungs of animals and humans, each of these vital natural processes rely on Henry's Law.

Henry's Law is a fundamental law of physical chemistry which naturally regulates and controls the Earth's atmospheric content of CO_2. This

counteracts any net CO_2 increases in the atmosphere caused by the worldwide combustion of hydrocarbon fuel sources.

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Sander, R. Compilation of Henry's law constants (version 4.0) for water as solvent R. Sander. Atmos. Chem. Phys., 15, 4399–4981, 2015 https://www.atmos-chem-phys.net/15/4399/2015/ doi:10.5194/acp-15-4399-2015

Regarding Graham's law of effusion and diffusion:
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https://en.wikipedia.org/wiki/Thomas_Graham_(chemist)
https://en.wikipedia.org/wiki/Graham%27s_law

Pinatubo Study
climatecite.com
our plan to overturn the climate change alarmism and green energy
movements

Henry's Law Constants

Global sea-air CO_2 flux based on climatological surface ocean pCO_2, and seasonal biological and temperature effects. Taro Takahashi a, Stewart C. Sutherland a, Colm Sweeney a, Alain Poisson b, Nicolas Metzl b, Bronte Tilbrook c, Nicolas Bates d, Rik Wannink$_H$of e, Richard A. Feely f, Christopher Sabine f, Jon Olafsson g, Yukihiro Nojiri December 2002. Deep Sea Research Part II Topical Studies in Oceanography 49(9-10):1601-1622. DOI: 10.1016/S0967-0645(02)00003-6. Downloadable pdf here: https://www.researchgate.net/publication/232259896_Global_sea-air_CO_2_flux_based_on_climatological_surface_ocean_pCO_2_and_seasonal_biological_and_temperature_effects

(This reference above is one of many papers by this large group of climate modelers who are focused on CO_2 and the air ocean interface. Primarily they are working on their modeling and algorithm technologies. Also referenced and summarized here. https://www.ldeo.columbia.edu/res/pi/CO_2/carbondioxide/pages/air_sea_flux_2000.html. They have a paper in 2015 which I have not yet read. Henry's Law is implicit in these work but rarely if ever mentioned. Mike Brown referenced on of their papers.)

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A Gas Chromatographic Method for the Determination of Bicarbonate and Dissolved Gases

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The Solubility of Carbon Dioxide in Water at Low Pressure. John J. Carroll, John D. Slupsky, Alan E. Mather; J. Phys. Chem. Ref. data 1 November 1991; 20 (6): 1201–1209. https://doi.org/10.1063/1.555900 (avail in pdf only $40.) Abstract: "The system carbon dioxide-water is of great scientific and technological importance. Thus, it has been studied often. The literature for the solubility of carbon dioxide in water is vast and interdisciplinary. An exhaustive survey was conducted and approximately 100 experimental investigations were found that reported equilibrium data at pressures below 1 MPa. A model based on Henry's law was used to correlate the low pressure data (those up to 1 MPa). The following correlation of the Henry's constants (expressed on a mole fraction basis) was developed $\ln(H_{21}/MPa) = -6.8346 + 1.2817 \times 10^4/T - 3.7668 \times 10^6/T^2 + 2.997 \times 10^8/T^3$ The correlation is valid for $273 < t < t$

William Henry Biographical Sketch

William Henry, M.D., (1774-1836) an English chemist, beginning in 1803 published results from an extensive series of his experiments on various gases and their solubilities, partial pressures, and

other properties when these various gases are in contact with various liquids. His results were published along with a series of his chemistry lectures in at least eight editions including Volume I Eighth Edition in 1818 by The Royal Society of London (1) of which Dr. Henry was a fellow. Henry's work was reviewed by Mr. John Dalton, (1766-1844) English chemist, physicist and meteorologist, famously renown for his atomic theory including today's method for establishing atomic weights for the chemical elements, and Dalton's Law of partial pressures.(2) The Dalton (Da) in The International System of Units (SI) is named after John Dalton; one Dalton is defined as an atomic mass equal to one twelfth of the mass of a neutral carbon atom, which is equal to one hydrogen atom. Dalton and Henry were not without opposition. English Scientist Dr. William Hyde Wollaston (1766-1828), also a Fellow of the Royal Society of London, and Irish mathematician Dr. James Thomson, (1776-1849) father of famous scientist William Thomson Lord Kelvin, and Swedish scientist Professor Baron Jöns Jacob Berzelius (1779-1848), on the other hand, asserted oxygen as the decimal unit of atomic weight and reviewed the works of both Dalton and Henry.

"The principle, on which gases are absorbed and retained by liquids, is still a subject of controversy. By Berthollet, Thomson, Saussure, and the generality of chemists, it is ascribed to the exertion of a chemical affinity between the gas and the liquid; but it is contended by Mr. Dalton and myself that the effect in most cases is chiefly, if not wholly, mechanical."

As discussed in the following paragraphs, Dalton and Henry held against their contemporary critics that the principle was mechanical, that is the principle is physical, not chemical. They demonstrated by ingenious experiments and reports by others to their scientific critics, for example:

"The general inference from his [i.e. De Grotthus'] experiments is, that the intensity of electric light is always in a direct proportion to the density of the gas, and in the inverse proportion to the conducting power of the gas for electricity."

"The comparative soniferous properties of the gases have been determined by Messrs, Kerby and Merrick; but as these belong rather to mechanical than to chemical science, I shall content myself with referring to the account of them in the 27th and 33d volumes of Nicholson's Journal, and in the 45th volume of the Philosophical Magazine." (1) page 134.

Today, misunderstanding of this critical difference between physics and chemistry leads to the ongoing failure to understand and correctly compute the Henry's Law proportionality of carbon dioxide gas between air and water, with the result that existential sums of money are being squandered in the false belief that humans must reduce atmospheric carbon dioxide concentration. The absorbance of any gas into any liquid and the emission of any gas from any liquid is a physical phase-state reaction, that is, a change in the physical state of the gas, for example:

- its total pressure and partial pressures,

- its temperature and thermal dynamics,

- directional motions and migrations of its constituent molecules

- its volume and density

- the masses and sizes of the constituent molecules.

- the boiling point, freezing point, triple point, sublimation conditions

- specific heat

- opacity

In the bulleted list just above, the identity of the gas nor the amount of the gas changed, and the identity of the liquid nor the amount of the liquid changed. On the other hand, a chemical reaction of a gas and the liquid creates one or more new chemical product entities by changing or combing the reactant entities.

William Henry, confirmed by John Dalton and thousands of other scientists since them, discovered that a gas partitions between a liquid and a volume of gas in contact with that liquid, and that the partition ratio is a physical property like a boiling point or specific heat; these are properties which are not changed by the amount of matter present. Henry demonstrated that the partition ratio is a function of the absolute temperature of the liquid. That is, colder liquids absorb more gas than they emit and warmer liquids emit more gas than they absorb.

In other words, adding carbon dioxide to the atmosphere by burning fossil fuels does not increase the concentration of carbon dioxide in the atmosphere. A carbon dioxide concentration in air which exceeds the Henry's Law ratio for a given water temperature will be absorbed by water. Any carbon dioxide removed from air will be replaced from water and water containing surfaces everywhere until the Henry's ratio is restored for the local water temperature. Life evolved under this dynamic condition.

Obituary for William Henry, MD, FRS
"The last name that occurs in the melancholy list of our departed compatriot associates is that of Dr William Henry, to whom the science of chemistry generally and gaseous chemistry in particular, is under great obligation. He was the author of nine papers in our Transactions, many of them of great merit; and his System of Chemistry is one of the best written and best arranged compendiums of that important and extensive science which has been published of late years, whether in our own language or in any other. The Memoirs of the Manchester Society are chiefly indebted to him, in conjunction with Dr Dalton, for the high character which they have so long maintained. Dr. Henry, like Dr. Wollaston, made the results of science, obtained by the most original and difficult researches, the foundation of a splendid fortune, and few persons have contributed more effectually to the promotion of those arts and manufactures which form the foundation of the prosperity of a great commercial nation." (3)

The elements of experimental chemistry, by Henry, William, 1774-1836. Dedicated to John Dalton (about 47 megabytes in pdf, on file). Here is link for download or reading online: https://archive.org/details/b29329875_0001/mode/2up Experiments on the quantity of gases absorbed by water, at different temperatures, and under different pressures. William Henry. Published:01 January 1832 https://doi.org/10.1098/rspl.1800.0063 and https://royalsocietypublishing.org/doi/abs/10.1098/rspl.1800.0063 2 pages.

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(Pdf) https://royalsocietypublishing.org/doi/pdf/10.1098/rsnr.2003.0194 page 18 (Note, John Dalton appointed William Charles Henry, MD (1804-1892) as his biographer. William Charles Henry MD was youngest son of our William Henry MD. Our William Henry MD committed suicide and pre-deceased Dalton).

This website was researched and composed by Claire (Bud) Bromley at https://budbromley.blog/, and Tomer D. Tamarkin at https://tamarkin.us.

Notice of any errors, omissions, corrections, and suggestions may be emailed to: tomer@henryslaw.org