Henry’s Law

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William Henry gave a quantitative relationship between solubility of a gas in a solvent and pressure which is known as Henry's law.

“The law states that the mass of a gas dissolved per unit volume of the solvent at a constant temperature is directly proportional to the pressure of the gas in equilibrium with the solution”.

$m \propto p \Rightarrow m = Kp$, where m is mass of a gas and p is pressure of the gas in equilibrium.

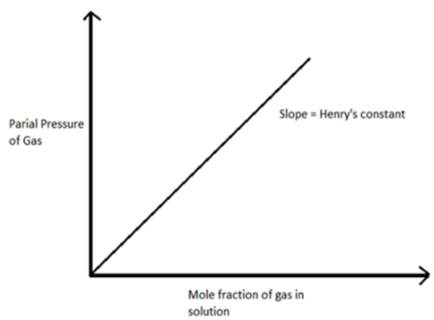
The proportionality constant K depends on the nature of gas, nature of the solvent, temperature and the units of pressure. Now if we use mole fraction of the gas in the solution as a measure of the solubility.

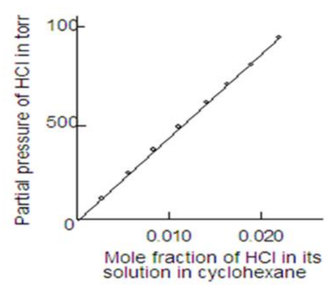
“Mole fraction of the gas in the solution is proportional to the partial pressure of the gas over the solution”.

$$x \;\alpha\; p \text{ or } x = K'p$$

$p = x.1/K' = K_H.x$ [$K_H = 1/K'$]. Here, K_H is called Henry’s law constant.

“Law may be stated as the partial pressure of the gas in the vapours phase is proportional to the mole fraction of the gas in the solution”.





A straight line passing through the origin is obtained. Shows the validity of Henry's law. Slope of line gives the Henry's law constant K_H. This K_H for different gas have different value, at the same temperature. This suggests that K_H is a function of the nature of the gas.

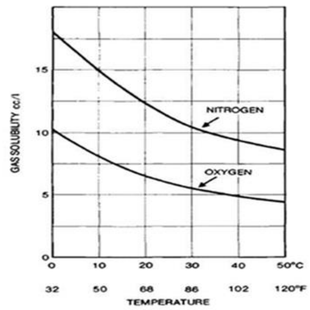
When a mixture of number of gases is brought in contact with a solvent, each constituent gas dissolves in proportion to its own partial pressure. Therefore, Henry's law is applied to each gas independent of the pressure of other gas.

The Henry’s law constant values for gases in water at 298K

Gas	Temp/K	K_H/kbar
He	293	144.97
H_2	293	69.16
N_2	293	76.48
N_2	303	88.84
O_2	293	34.86
O_2	393	46.82

Higher value of K_H at a particular temperature the lower is the solubility of the gas in the liquid. The K_H value for both nitrogen and oxygen increase with increase in temperature indicating that solubility of gases decreases with increase of temperature. This is reasoning that aquatic species are more comfortable in cold water rather than warm water.

Solubilities of oxygen and nitrogen in water at various temperatures



Applications of Henry's law:

1. In the production of carbonated beverages: To Increase the solubility of CO_2 in soft drinks, soda water, bear or champagne, the bottles are sealed under high pressure. When the bottle is open under normal atmospheric conditions, the pressure inside the bottle falls to atmospheric pressure and the excess carbon dioxide bubbles out of the solution causing the effervescence.

2. In the function of lungs: To minimize the painful effect of deep-sea divers during the decompression, oxygen diluted with less soluble helium gas is used as breathing gas.

2. In deep sea diving (Scuba diving): Deep Sea diver depends upon compressed air for breathing at high pressure under water. The compressed air contains nitrogen in addition to oxygen, which are not very soluble in blood at normal pressure. However, at great depths and the diver breaths in compressed air from the supply tank, more nitrogen dissolved in blood and other body fluids because the pressure at that death is far greater than the surface atmospheric pressure. When the diver comes towards the surface, the pressure decreases, nitrogen come out of the body quickly farming bubble in the blood stream. These bubbles restrict blood flow after effect the transmission of nerve impulses.

The bubbles can even burst the capillaries or blocked them and starve the tissues of oxygen. This condition is called 'the bends' which are painful and dangerous to life. To avoid this condition most professional diver these days use air diluted with helium gas (about 11.7%, 56.2% nitrogen and 32.1% oxygen) because of lower solubility of helium in the blood than nitrogen. Moreover, because of small size of Helium atom than nitrogen molecules, they can pass through cell walls without damaging them. the excess O2 dissolved in blood is used in metabolism and does not cause the condition of bends.

4. At high altitudes. At high altitudes the partial pressure of oxygen is less than that at the ground level. This results in low concentration of oxygen in the blood and tissues of the people living at high altitudes or climbers. The low blood oxygen causes climbers to become weak and unable to think clearly known as anoxia.

Assignment

1. Low concentration of oxygen in the blood and tissues of people living at higher altitudes is due to……..
(A) low temperature
(B) low atmospheric pressure
(C) high atmospheric pressure
(D) both low temperature and high atmospheric pressure

2. the value of Henry's constant, K_H is …….

(A) greater for gases with highest solubility
(B) greater for gases with lower solubility
(C) constant for all gases
(D) not related to the solubility of gases

3. At high altitude the boiling point of water decreases because:

(A) that atmospheric pressure is high
(B) the temperature is low
(C) the atmospheric pressure is low
(D) the temperature is high

4. A pressure cooker reduces cooking time because:

(A) heat is more evenly distributed
(B) the high pressure tenderizes the food
(C) the boiling point of water inside the cooker is elevated
(D) the boiling point of water inside the cooker is depressed

5. At a same temperature, hydrogen is more soluble in water than helium. Which of them will have a higher value of K_H and why?

(A) helium will have higher value because if gas has more solubility, its K_H value is lower
(B) helium will have lower value of K_H because if gas has more solubility, its K_H value is lower
(C) helium will have higher value of K_H because if gas has less solubility its K_H value is lower
(D) none of these

6. Henry's law is not applicable for:

(A) ammonia in water
(B) nitrogen in water
(C) carbon dioxide in water
(D) xenon in water

ANSWERS

1. (B) 2. (B) 3. (C) 4. (C) 5. (A) 6. (A)