Water Potential: Components and Osmotic Relations of Cells

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Abstract:

Water potential is a measure of **the potential energy in water** as well as the difference between the potential in a given water sample and pure water. ... The internal water potential of a plant cell is more negative than pure water; this causes water to move from the soil into plant roots via osmosis..

Water potential term was coined by Slatyer and Taylor (1960). It is modern term which is used in place of DPD. The movement of water in plants cannot be accurately explained in terms of difference in concentration or in other linear expression.

The best way to express spontaneous movement of water from one region to another is in terms of the difference of free energy of water between two regions (from higher free energy level to lower free energy level).

According to principles of thermodynamics, every components of system is having definite amount of free energy which is measure of potential work which the system can do. Water Potential is the difference in the free energy or chemical potential per unit molar volume of water in system and that of pure water at the same temperature and pressure.

Key words: Water potential is a measure of the potential energy in water, pure water at the same temperature and pressure

Introduction:

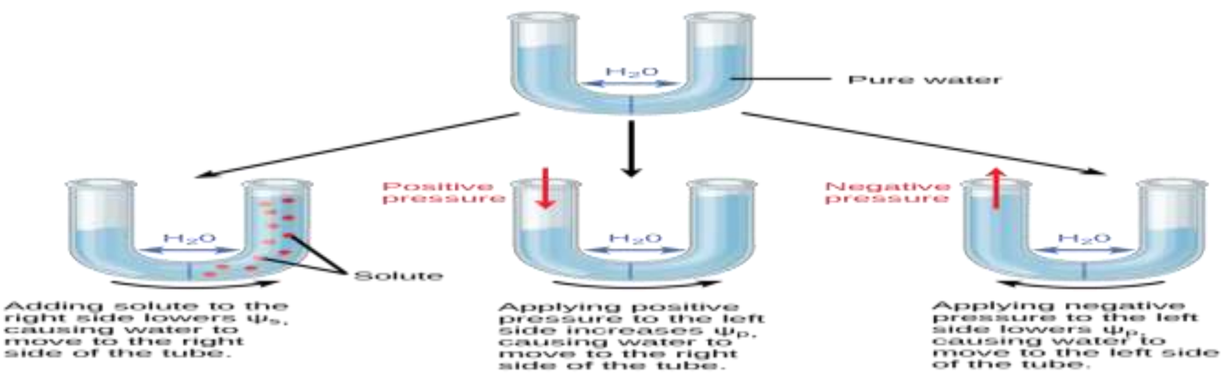
It is represented by Greek letter or the value of is measured in bars, pascals or atmospheres. Water always moves from the area of high water potential to the area of low water potential. Water potential of pure water at normal temperature and pressure is zero. This value is considered to be the highest. The presence of solid particles reduces the free energy of water and decreases the water potential. Therefore, water potential of a solution is always less than zero or it has negative value.

Cells are the basic structural units of organisms, and plant organization varies from single cells to aggregations of cells to complex multicellular structures. With increasing complexity there are increasingly sophisticated systems for absorbing water, moving it large distances, and conserving it but fundamentally the cell remains the central unit that controls the plant response to water. The driving forces for water movement are generated in the cells, and growth and metabolism occur in the aqueous medium provided by the cells.

The cell properties can change and result in acclimation to the water environment. As a consequence, many features of complex multicellular plants can be understood only from a knowledge of the cell properties. This chapter is concerned with those properties and how they are measured. Later chapters will consider the whole organism more fully and will use the principles described here for the cells.

Components of Water Potential:

A typical plant cell consists of a cell wall, a vacuole filled with an aqueous solution and a layer of cytoplasm between vacuole and cell wall. When such a cell is subjected to the movement of water then many factors begin to operate which ultimately determine the water potential of cell sap.



For solution such as contents of cells, water potential is determined by 3 major sets of internal factors:

(a) Matrix potential (Ψ_m)

(b) Solute potential or osmotic potential (Ψ_s)

(c) Pressure potential (Ψ_p)

Water potential in a plant cell or tissue can be written as the sum of matrix potential (due to binding of water to cell and cytoplasm) the solute potential (due to concentration of dissolve solutes which by its effect on the entropy components reduces the water potential) and pressure potential (due to hydrostatic pressure, which by its effect on energy components increases the water potential).

$\Psi_w = \Psi_s + \Psi_p + \Psi_m$

In case of plant cell, m is usually disregarded and it is not significant in osmosis. Hence, the above given equation is written as follows.

$\Psi_w = \Psi_s + \Psi_p$

Solute Potential (Ψ_s):

It is defined as the amount by which the water potential is reduced as the result of the presence of the solute, s are always in negative values and it is expressed in bars with a negative sign.

Pressure Potential (Ψ_p):

Plant cell wall is elastic and it exerts a pressure on the cellular contents. As a result the inward wall pressure, hydrostatic pressure is developed in the vacuole it is termed as turgor pressure. The pressure potential is usually positive and operates in plant cells as wall pressure and turgor pressure. Its magnitude varies between +5 bars (during day) and +15 bars (during night).

Important Aspects of Water Potential (Ψ_w):

(1) Pure water has the maximum water potential which by definition is zero.

(2) Water always moves from a region of higher Ψ_w to one of lower Ψ_w.

(3) All solutions have lower w than pure water.

(4) Osmosis in terms of water potential occurs as a movement of water molecules from the region of higher water potential to a region of lower water potential through a semi permeable membrane.

Osmotic Relations of Cells According to Water Potential:

In case of fully turgid cell:

The net movement of water into the cell is stopped. The cell is in equilibrium with the water outside. Consequently the water potential in this case becomes zero. Water potential is equal to osmotic potential + pressure potential.

In case of flaccid cell:

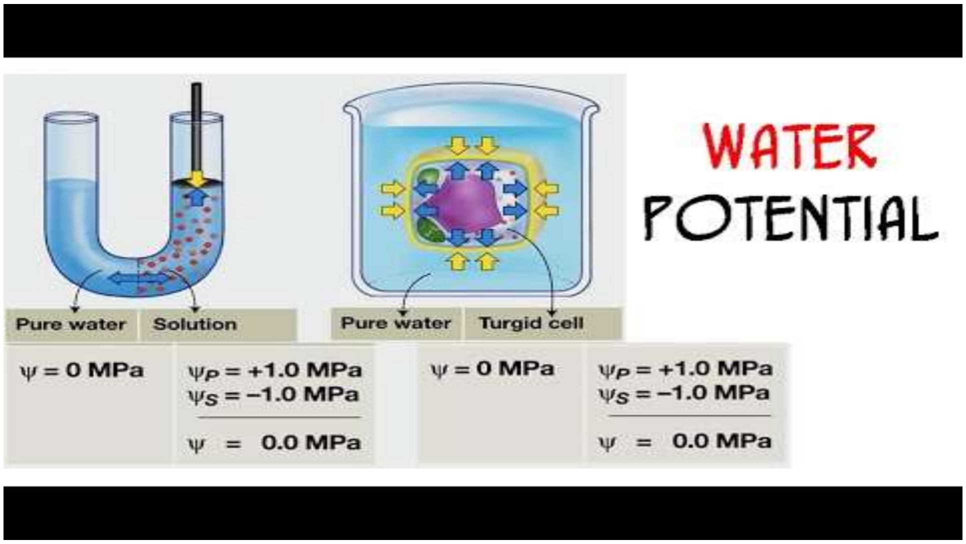
The turgor becomes zero. A cell at zero turgor has an osmotic potential equal to its water potential.

In case of plasmolysed cell:

When the vacuolated parenchymatous cells are placed in solutions of sufficient strength, the protoplast decreases in volume to such an extent that they shrink away from the cell wall and the cells are plasmolysed. Such cells are negative value of pressure potential (negative turgor pressure).

Water Potential: Measurements, Methods and Components

n recent years the term chemical potential of water is replaced by water potential. This is designated by the Greek letter psi (Ψ). Water potential is measured in bars. The latter is a pressure unit. When the water potential in a plant cell or tissue is low the latter is capable of absorbing water.



On the other hand, if the water potential of the cell tissue is high it indicates their ability to make available water to the desiccating surrounding cells. Clearly water potential is used as a measure to determine whether the tissue is under water stress or water deficit.

Numerical Problems:

1. Suppose there are two cells A and B, cell A has osmotic potential = -16 bars, pressure potential = 6 bars and cell B as osmotic potential = – 10 bars and pressure potential = 2 bars. What is the direction of movement of water?

Water potential of cell A = $\Psi_s + \Psi_p$ = – 16 + 6 = – 10 bars

Ψ of cell B = -10 + 2 = -8 bars.

As movement of water is from higher water potential (lower DPD) to lower water potential (higher DPD), hence the movement of water is from cell B to cell A.

2. If osmotic potential of a cell is – 14 bars and its pressure potential is 7 bars. What would be its water potential?

We know $\Psi_w = \Psi_s + \Psi_p$

Given, osmotic potential (Ψ_s) is – 14 bars.

Pressure potentials (Ψ_p) is 7 bars

Therefore,

Water potential = (-14) + 5 = – 9 bars.

What is water homeostasis?

Whilst water in the human body is found in plasma and the intestine, the overwhelming majority is found within cells. As humans continuously lose water through urine and feces, perspiration, and respiration, a finely balanced and sensitive network of physiological controls is necessary to maintain water levels. This is body water homeostasis, which is maintained by stimulating fluid intake by thirst.

Thirst is a biological instinct, mediated by sensory receptors called osmoreceptors. These receptors are located in the hypothalamus and detect changes in blood plasma. When they detect low blood volume, they signal to the hypothalamus which in turn generates the sensation of thirst. This homeostatic control mechanism ensures a balance between fluid loss and fluid intake.

Hydration

Ensuring adequate fluid intake is critical for many functions. These include:

- Body temperature regulation: Humans are designed to regulate body temperature, particularly when exposed to hot conditions such as a hot climate or during exercise. Losing water through the skin (perspiration) cools the body and helps to maintain homeostatic temperature. Without replacing the lost fluid, however, body temperature will rapidly increase.
- Removing bodily waste: Metabolic processes generate waste products that would otherwise harm the body if retained. Water acts as a solvent for waste products, dissolving them and allowing them to pass out of the body via urine and perspiration.

Water is an essential element for life. The prevention of dehydration is a critical component to survival: without water, humans can only survive for a few days. As water is the most plentiful molecule inside a cell, it comprises much of the body weight in humans, approximately 75% of body mass in infants and 55% of the mass in the elderly. However, as humans are constantly losing water, maintaining water homeostasis is vital.

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