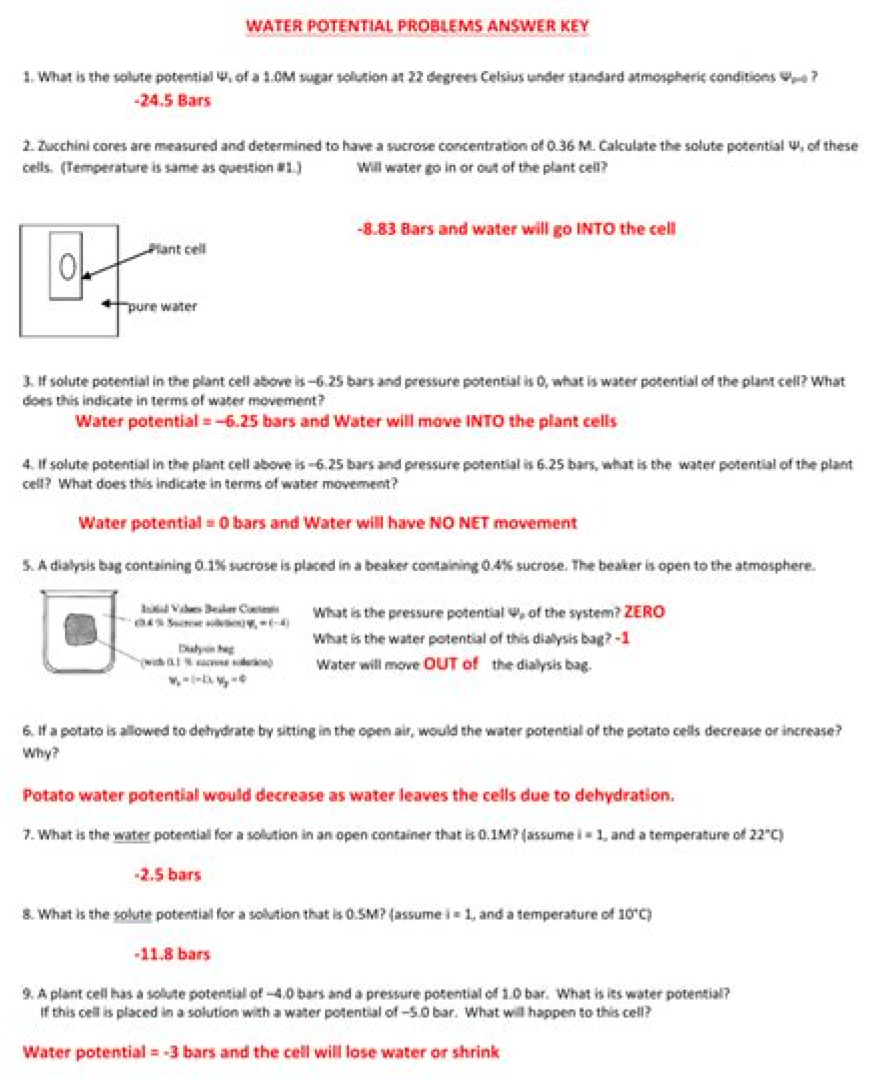
Water Potential Practice Problems



WATER POTENTIAL PROBLEMS ANSWER KEY

1. What is the solute potential Ψ_s of a 1.0M sugar solution at 22 degrees Celsius under standard atmospheric conditions $\Psi_{p=0}$?

-24.5 Bars

2. Zucchini cores are measured and determined to have a sucrose concentration of 0.36 M. Calculate the solute potential Ψ_s of these cells. (Temperature is same as question #1.) Will water go in or out of the plant cell?

-8.83 Bars and water will go INTO the cell

Plant cell

pure water

3. If solute potential in the plant cell above is −6.25 bars and pressure potential is 0, what is water potential of the plant cell? What does this indicate in terms of water movement?

Water potential = −6.25 bars and Water will move INTO the plant cells

4. If solute potential in the plant cell above is −6.25 bars and pressure potential is 6.25 bars, what is the water potential of the plant cell? What does this indicate in terms of water movement?

Water potential = 0 bars and Water will have NO NET movement

5. A dialysis bag containing 0.1% sucrose is placed in a beaker containing 0.4% sucrose. The beaker is open to the atmosphere.

Initial Values Beaker Contents (0.4 % Sucrose solution) $\Psi_s = (-4)$

Dialysis bag (with 0.1 % sucrose solution) $\Psi_s = (-1)$, $\Psi_p = 0$

What is the pressure potential Ψ_p of the system? ZERO

What is the water potential of this dialysis bag? -1

Water will move OUT of the dialysis bag.

6. If a potato is allowed to dehydrate by sitting in the open air, would the water potential of the potato cells decrease or increase? Why?

Potato water potential would decrease as water leaves the cells due to dehydration.

7. What is the water potential for a solution in an open container that is 0.1M? (assume i = 1, and a temperature of 22°C)

-2.5 bars

8. What is the solute potential for a solution that is 0.5M? (assume i = 1, and a temperature of 10°C)

-11.8 bars

9. A plant cell has a solute potential of −4.0 bars and a pressure potential of 1.0 bar. What is its water potential? If this cell is placed in a solution with a water potential of −5.0 bar. What will happen to this cell?

Water potential = -3 bars and the cell will lose water or shrink

Water potential practice problems are essential for students studying plant biology and physiology. Understanding water potential is critical for grasping how plants absorb, transport, and utilize water. Water potential (Ψ) is the measure of the potential energy of water in a system and is influenced by solute concentration and pressure. It plays a significant role in determining the direction of water movement in plants and across cell membranes. This article will explore the concept of water potential, its components, and provide practice problems to enhance understanding.

Understanding Water Potential

Water potential is represented by the Greek letter psi (Ψ) and can be expressed with the following equation:

$$ Ψ = Ψ_s + Ψ_p $$

Where:
- $Ψ_s$ = solute potential (osmotic potential)
- $Ψ_p$ = pressure potential

Components of Water Potential

1. Solute Potential ($Ψ_s$):
- Solute potential refers to the effect of solute concentration on the overall water potential. It is always negative or zero, as it represents the tendency of water to move into a solution.
- The formula to calculate solute potential is given by:

$$ Ψ_s = -iCRT $$

Where:
- i = ionization constant (number of particles the solute dissociates into)
- C = molar concentration of the solute
- R = pressure constant (0.0831 liter bar per mole per Kelvin)
- T = temperature in Kelvin (K = °C + 273)

2. Pressure Potential ($Ψ_p$):
- Pressure potential is the physical pressure on a solution. It can be positive or negative, with positive values typically found in turgid plant cells due to internal pressure exerted by the cell wall.
- In the case of open systems, like a plant cell, pressure potential can be equal to the turgor pressure, while in a closed system, it may be influenced by external pressure.

Water Movement in Plants

Water potential helps in understanding how water moves within plants. The movement of water occurs from regions of higher water potential to regions of lower water potential. Here are key points related to water movement:

- Transpiration: Water evaporates from the stomata, creating a negative pressure that pulls water upward from the roots.
- Osmosis: Water moves across semi-permeable membranes from areas of low solute concentration to areas of high solute concentration.
- Root Pressure: Generated when roots absorb water from the soil, potentially creating a positive pressure that pushes water upward.

Practice Problems

To solidify the understanding of water potential, here are a series of practice problems. Each problem is followed by its solution.

Problem 1: Calculating Solute Potential

A solution contains 0.2 M of sodium chloride (NaCl) at a temperature of 25°C. Calculate the solute potential (Ψ_s) of the solution.

Solution:
1. Determine ionization constant (i) for NaCl: i = 2 (Na^+ and Cl^-).
2. Convert temperature to Kelvin: T = 25 + 273 = 298 K.
3. Use the formula:

$$ \Psi_s = -iCRT $$
$$ \Psi_s = -2 \times 0.2 \, \text{mol/L} \times 0.0831 \, \text{L bar/(mol K)} \times 298 \, \text{K} $$
$$ \Psi_s = -9.92 \, \text{bar} $$

Problem 2: Total Water Potential Calculation

A plant cell has a solute potential of -1.5 MPa and a pressure potential of 0.5 MPa. Calculate the total water potential (Ψ).

Solution:
Using the equation:

$$ \Psi = \Psi_s + \Psi_p $$
$$ \Psi = -1.5 \, \text{MPa} + 0.5 \, \text{MPa} $$
$$ \Psi = -1.0 \, \text{MPa} $$

Problem 3: Water Movement Between Two Compartments

Two solutions are separated by a semi-permeable membrane. Compartment A has a water potential of -0.5 MPa, and Compartment B has a water potential of -1.0 MPa. Which direction will the water move, and why?

Solution:
Water moves from areas of higher water potential to lower water potential. Since -0.5 MPa (Compartment A) is higher than -1.0 MPa (Compartment B), water will move from Compartment A to Compartment B.

Problem 4: Estimating Water Potential Changes

A plant cell is placed in a hypertonic solution. Before being placed in the solution, the cell has a water potential of -0.3 MPa. If the cell loses water and its solute potential drops to -0.8 MPa, what will the new water potential be if the pressure potential remains 0?

Solution:
Since pressure potential (Ψ_p) is 0:

$$\Psi = \Psi_s + \Psi_p$$
$$\Psi = -0.8 \, \text{MPa} + 0$$
$$\Psi = -0.8 \, \text{MPa}$$

Conclusion

Understanding water potential is vital for comprehending how plants interact with their environment. The practice problems presented demonstrate the application of the concepts of solute potential and pressure potential in real-world scenarios. By mastering these problems, students can better appreciate the intricate mechanisms of water movement within plant systems, facilitating learning in plant physiology and ecology. Further exploration and practice will deepen understanding and enhance skills in evaluating water potential in various biological contexts.

Frequently Asked Questions

What is water potential and how is it calculated?

Water potential is the measure of the potential energy of water in a system and is calculated using the formula $\Psi = \Psi_s + \Psi_p$, where Ψ is the water potential, Ψ_s is the solute potential, and Ψ_p is the pressure potential.

How does solute concentration affect water potential?

As solute concentration increases, the solute potential (Ψ_s) becomes more negative, which lowers the overall water potential (Ψ) of the solution.

What is the difference between osmotic potential and pressure potential?

Osmotic potential (or solute potential) refers to the effect of solutes on water potential, while pressure potential refers to the physical pressure exerted on the water in a system, such as the turgor pressure in plant cells.

How do you calculate the water potential of a plant cell in a hypertonic solution?

In a hypertonic solution, the water potential of the plant cell can be calculated by determining the solute potential using the formula $\Psi_s = -iCRT$ (where i is the ionization constant, C is the molar concentration, R is the ideal gas constant, and T is the temperature in Kelvin) and adding it to the pressure potential, which is typically zero in a flaccid cell.

What happens to plant cells when placed in a hypotonic solution?

When plant cells are placed in a hypotonic solution, water enters the cells, increasing turgor pressure and making the cells turgid, as the water potential inside the cell becomes more positive compared to the surrounding solution.

What role does water potential play in plant water uptake?

Water potential drives the movement of water from the soil into plant roots; water moves from areas of higher water potential (the soil) to areas of lower water potential (the roots) until equilibrium is reached.

How can you determine if a solution is isotonic with a cell?

A solution is isotonic with a cell when the water potential of the solution equals the water potential of the cell, resulting in no net movement of water in or out of the cell.

What is the significance of measuring water potential in agricultural practices?

Measuring water potential is significant in agriculture as it helps determine the water status of plants, guiding irrigation practices to ensure optimal water availability for crop growth and preventing water stress.

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