



Water potential

Revision notes • IB Biology D2.3: solvation, osmosis and tonicity, effects on cells with and without walls, isotonic solutions in medicine and (HL) water potential.

For IB Diploma Biology, Standard Level and Higher Level (first assessment 2025). **HL only** is additional higher level content, for HL students only.

Water potential Spec D2.3

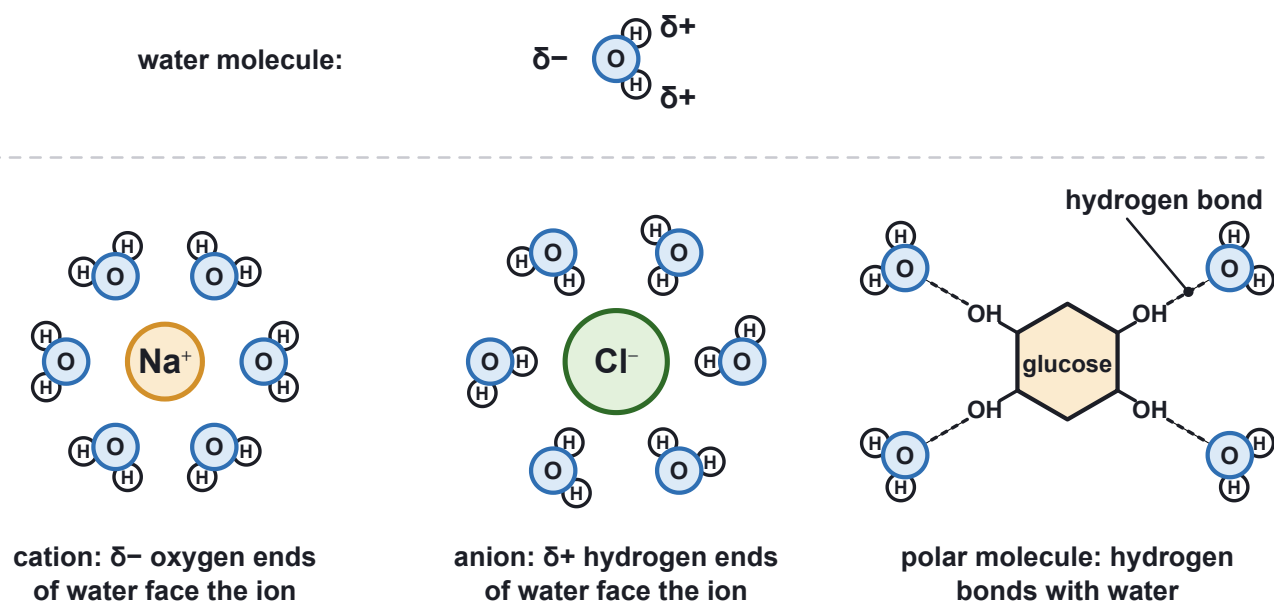
Solvation and osmosis Spec D2.3.1, D2.3.2, D2.3.3

Solvation

Solvation is the process of a solute dissolving, with each solute particle surrounded by solvent molecules. Water is a good solvent because its molecules are **polar**: the oxygen end is slightly negative (δ^-) and the hydrogen ends are slightly positive (δ^+).

- **Positively charged ions** (for example Na^+) attract the δ^- oxygen ends of water molecules.
- **Negatively charged ions** (for example Cl^-) attract the δ^+ hydrogen ends of water molecules.
- **Polar molecules** such as glucose form **hydrogen bonds** with water molecules.

Each ion or molecule becomes surrounded by a shell of water molecules, so it separates from the others and dissolves.



[\(opens full size in a new tab\)](#)

Solvation: polar water molecules surround cations, anions and polar molecules such as glucose, so they dissolve.

Direction of water movement

Osmosis is the net movement of water through a partially permeable membrane. Water moves **from the less concentrated solution to the more concentrated solution**, meaning from lower to higher **solute**

concentration. Water molecules bound to solutes move less freely, so more water molecules cross from the side with fewer solutes.

Hypertonic	Having a higher solute concentration than another solution.
Hypotonic	Having a lower solute concentration than another solution.
Isotonic	Having the same solute concentration as another solution.

Osmosis into and out of cells

Predicting net movement of water	
Environment of the cell	Net movement of water
Hypotonic (lower solute concentration than the cytoplasm)	Into the cell
Hypertonic (higher solute concentration than the cytoplasm)	Out of the cell
Isotonic	No net movement: water moves in and out at equal rates (dynamic equilibrium)

Common mistake: Describe direction in terms of solute concentration, not water concentration. And in an isotonic solution water still moves; the rates in and out are just equal.

Osmosis in plant tissue: the practical Spec D2.3.4

When plant tissue is bathed in a **hypotonic** solution, water enters the cells by osmosis, so the tissue **gains mass and gets longer** and becomes firm. In a **hypertonic** solution water leaves, so the tissue **loses mass and gets shorter** and becomes soft.

1. Cut equal-sized cylinders of tissue (for example potato) with a cork borer and trim them to the same length.
2. Blot each cylinder dry, then measure its length and mass.
3. Place cylinders in a range of solute concentrations, for example sucrose solutions from 0.0 to 1.0 mol dm⁻³, with several repeats at each concentration.
4. Leave for the same time at the same temperature, then blot dry and measure length and mass again.
5. Calculate the percentage change in mass and length for each cylinder, and the mean for each concentration.

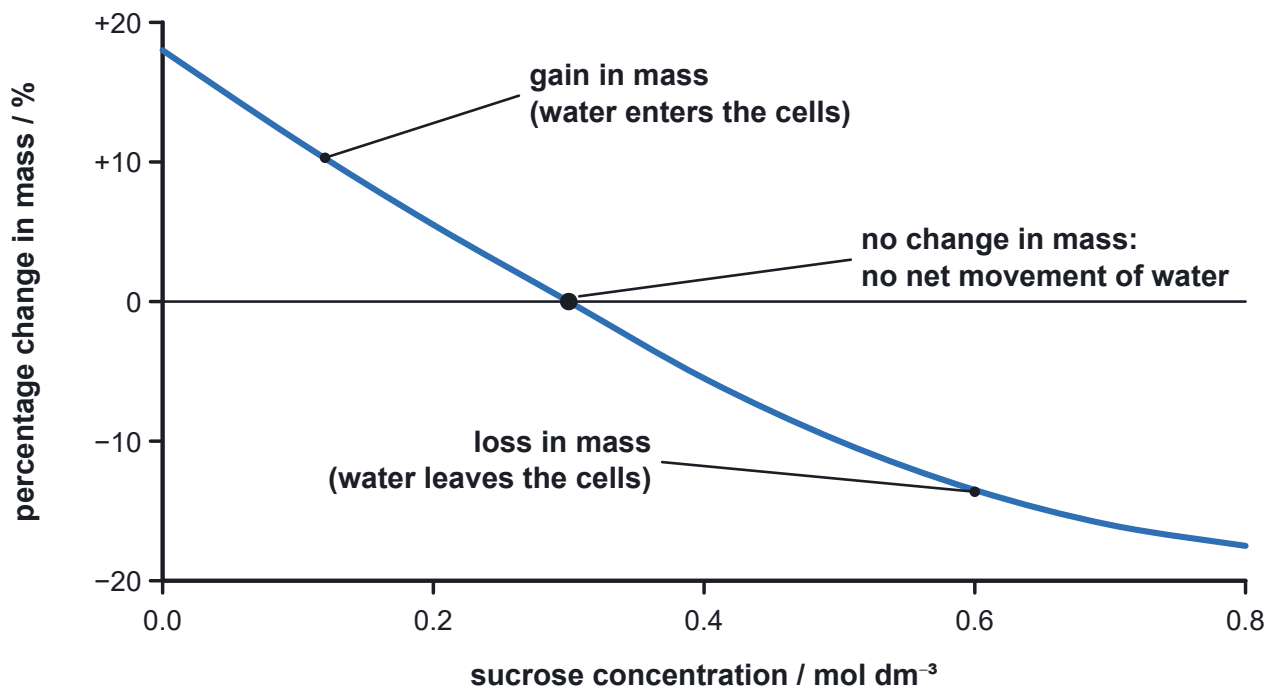
$$\text{percentage change} = (\text{final value} - \text{initial value}) \div \text{initial value} \times 100$$

Percentage change in mass

A potato cylinder has a mass of 2.50 g before and 2.20 g after 40 minutes in 0.6 mol dm⁻³ sucrose solution. Calculate the percentage change in mass.

1. Change in mass = 2.20 – 2.50 = –0.30 g.
2. Percentage change = –0.30 ÷ 2.50 × 100 = –12%.

Answer: –12% (a loss in mass, so the solution was hypertonic to the potato cells).



[\(opens full size in a new tab\)](#)

The **isotonic concentration** is where the line crosses zero percentage change: there is no net movement of water (illustrative data).

Percentage change is used because cylinders start with slightly different masses and lengths. The **isotonic solute concentration** of the tissue is deduced by reading where the line of best fit crosses **zero** percentage change.

Maths skill: With repeats at each concentration, calculate the standard deviation (spread of the repeats) and standard error (how precisely the mean is known) with a calculator or spreadsheet. Show standard error as error bars; you do not need to memorise the formulae.

Practical skill: Comparing standard errors lets you judge whether length or mass measurements were more reliable. If error bars of two means overlap widely, the difference between them may not be significant.

Water movement in cells with and without walls Spec D2.3.5, D2.3.6, D2.3.7

Cells that lack a cell wall

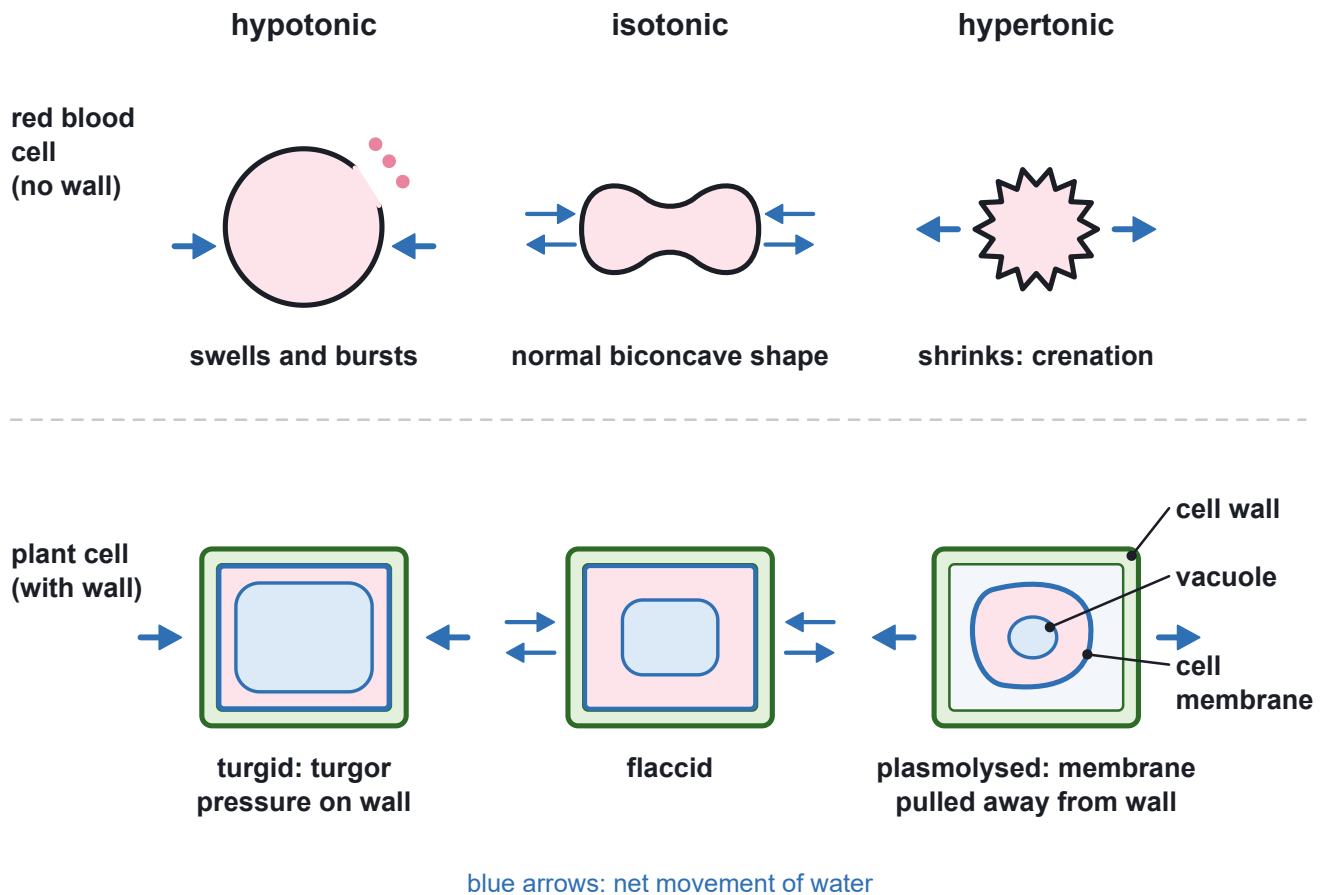
- **Hypotonic medium:** water enters, the cell **swells** and, with no wall to resist, may **burst** (red blood cells burst, called haemolysis).
- **Hypertonic medium:** water leaves, the cell **shrinks** and the membrane becomes wrinkled and spiky (**crenation**).

Freshwater unicellular organisms, such as *Paramecium*, live in a hypotonic environment and water constantly enters. They use **contractile vacuoles** to collect excess water and expel it from the cell, which needs energy from ATP. Without this the cell would burst.

In **multicellular organisms**, the tissue fluid that bathes cells must be kept **isotonic** with the cytoplasm to prevent harmful swelling or shrinkage. In humans, the kidneys regulate the solute concentration of blood plasma and so of tissue fluid.

Cells with a cell wall

- **Hypotonic medium:** water enters and the cytoplasm and vacuole push against the cell wall, developing **turgor pressure**. The wall resists further expansion, so the cell becomes **turgid** but does not burst. Turgor supports non-woody plant tissue.
- **Hypertonic medium:** water leaves, the cytoplasm and vacuole shrink and the cell membrane pulls away from the cell wall. This is **plasmolysis**. The cell becomes flaccid and the tissue wilts.



blue arrows: net movement of water

[\(opens full size in a new tab\)](#)

Cells without a wall **burst or crenate**; cells with a wall become **turgid** or **plasmolysed**.

Medical applications of isotonic solutions

- **Intravenous fluids:** fluids given into a vein as part of medical treatment, such as normal saline (0.9% sodium chloride), are isotonic with blood plasma so blood cells neither burst nor crenate.
- **Organs for transplantation:** donor organs are bathed in a cold isotonic solution, so their cells neither gain nor lose water while being stored and transported.

Exam tip: Linking question: how do plant and animal cells differ in their regulation of water movement? Plant cells rely on the cell wall and turgor; animal cells rely on keeping tissue fluid isotonic.

Water potential Spec D2.3.8, D2.3.9, D2.3.10, D2.3.11 HL only

Water potential (ψ_w) is the **potential energy of water per unit volume**. The absolute amount of potential energy cannot be measured, so values are given **relative to pure water at atmospheric pressure and 20°C**, which is defined as **zero**. The units are usually **kilopascals (kPa)**.

Movement from higher to lower water potential

Water always moves **from a higher water potential to a lower water potential**. This is the same as any movement that lowers potential energy, like a ball rolling downhill. Dissolving solutes lowers the

potential energy of water, because water molecules are held in shells around the solute particles. Pressure raises it.

Solute potential and pressure potential

$$\psi_w = \psi_s + \psi_p$$

Solute potential (ψ_s)	The effect of dissolved solutes on water potential. It ranges from zero (pure water) downwards: the more concentrated the solution, the more negative ψ_s .
Pressure potential (ψ_p)	The effect of pressure on water potential. It is generally positive inside cells, because the wall pushes back on the protoplast; it is negative in xylem vessels where sap is transported under tension.

Predicting the direction of water movement

A plant cell has a solute potential of -800 kPa and a pressure potential of $+300$ kPa. It is placed in a solution with a water potential of -650 kPa. Calculate the water potential of the cell and state the direction of net water movement.

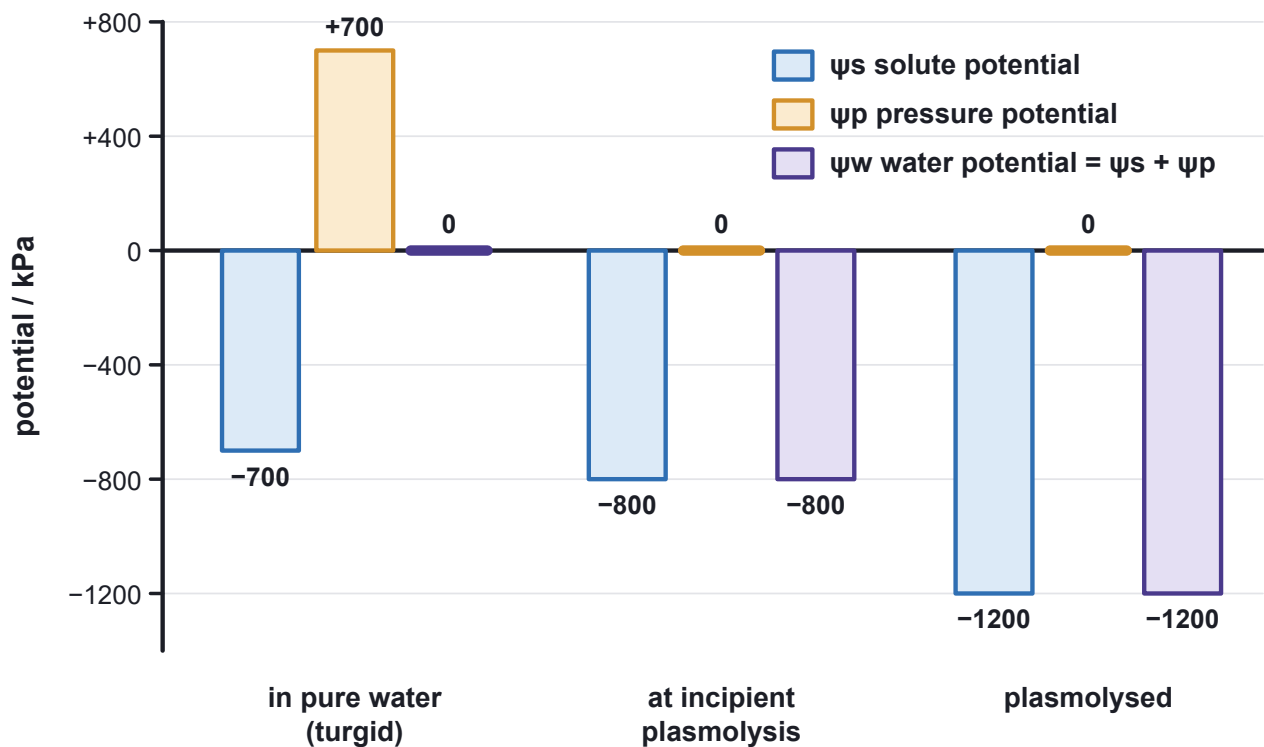
1. $\psi_w = \psi_s + \psi_p = -800 + 300 = -500$ kPa.
2. The solution (-650 kPa) has a lower water potential than the cell (-500 kPa).
3. Water moves from higher to lower water potential: out of the cell into the solution.

Answer: ψ_w of the cell = -500 kPa; net movement of water is out of the cell.

Water potential and plant tissue

Plant tissue bathed in hypotonic and hypertonic solutions

	Hypotonic solution	Hypertonic solution
Starting point	ψ_w of solution is higher than ψ_w of cells	ψ_w of solution is lower than ψ_w of cells
Water movement	Into the cells	Out of the cells
Change in ψ_s	Rises slightly (less negative) as the cell sap is diluted	Falls (more negative) as the cell sap becomes more concentrated
Change in ψ_p	Rises as the protoplast presses on the wall	Falls to zero as the cell becomes flaccid; it stays near zero during plasmolysis
End point	Net uptake stops when ψ_w of the cells equals ψ_w of the solution (the cells are turgid)	Net loss stops when ψ_w of the cells equals ψ_w of the solution (the cells are plasmolysed)



[\(opens full size in a new tab\)](#)

$\psi_w = \psi_s + \psi_p$: as the cell loses water, ψ_p falls to zero and ψ_w becomes more negative (illustrative values).

Exam tip: In pure water a turgid cell reaches $\psi_w = 0$ because ψ_p becomes equal and opposite to ψ_s . Always state values with their signs and units, and compare water potentials, not solute concentrations, when using this model.

Quick check

1. Why are cations and anions both able to dissolve in water?
2. In which direction does water move between a hypotonic and a hypertonic solution?
3. What is plasmolysis?
4. Why are intravenous fluids isotonic?
5. **HL only** What is the water potential of pure water at atmospheric pressure and 20°C?

Quick check answers

Water potential

1. Water is polar: cations attract the δ^- oxygen ends and anions attract the δ^+ hydrogen ends of water molecules.
2. From the hypotonic (less concentrated) solution to the hypertonic (more concentrated) solution.
3. The cell membrane pulling away from the cell wall as water leaves a plant cell in a hypertonic solution.
4. So that blood cells neither gain nor lose water, which would make them burst or crenate.
5. Zero (0 kPa).