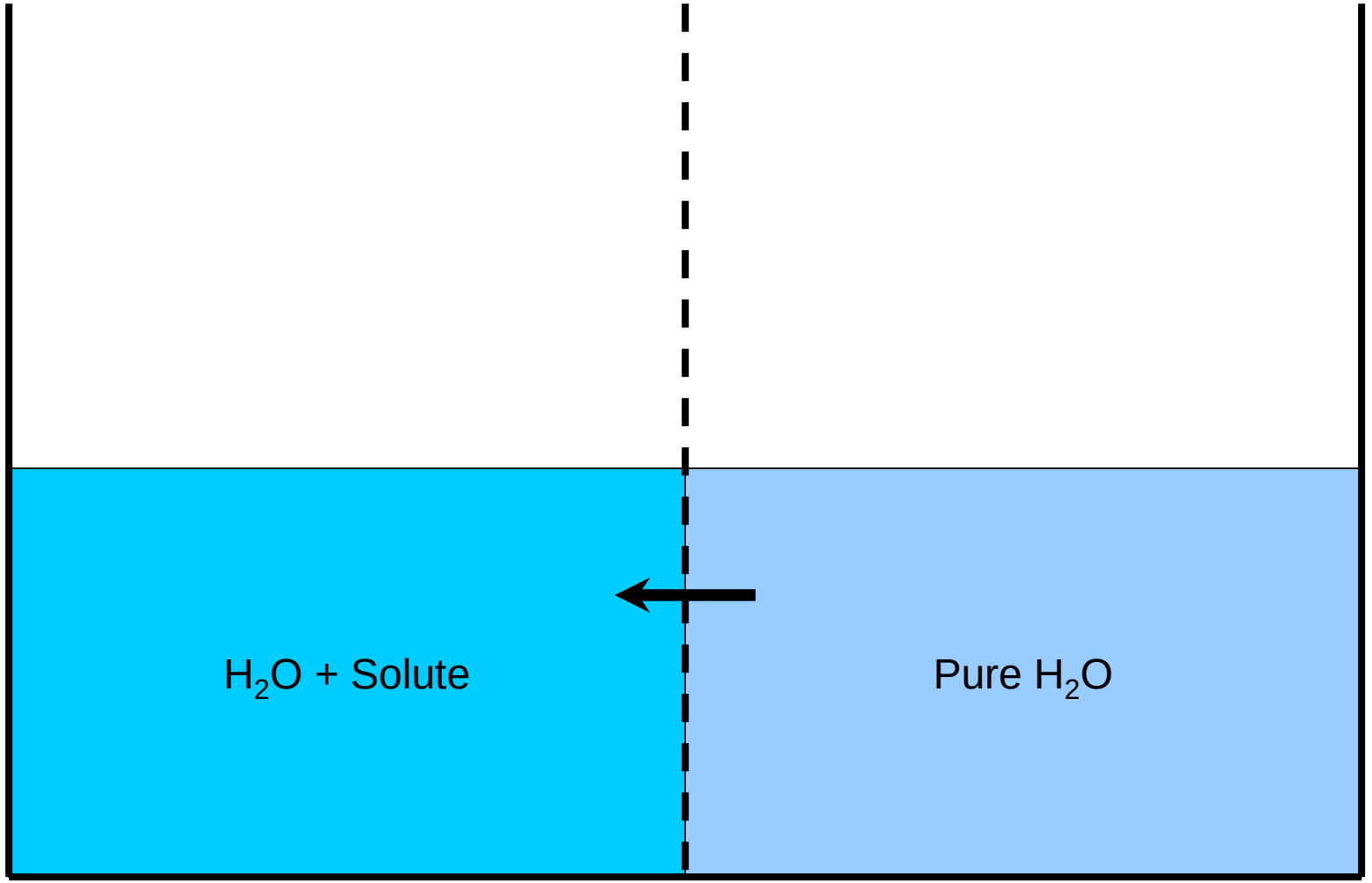
Chemistry 201

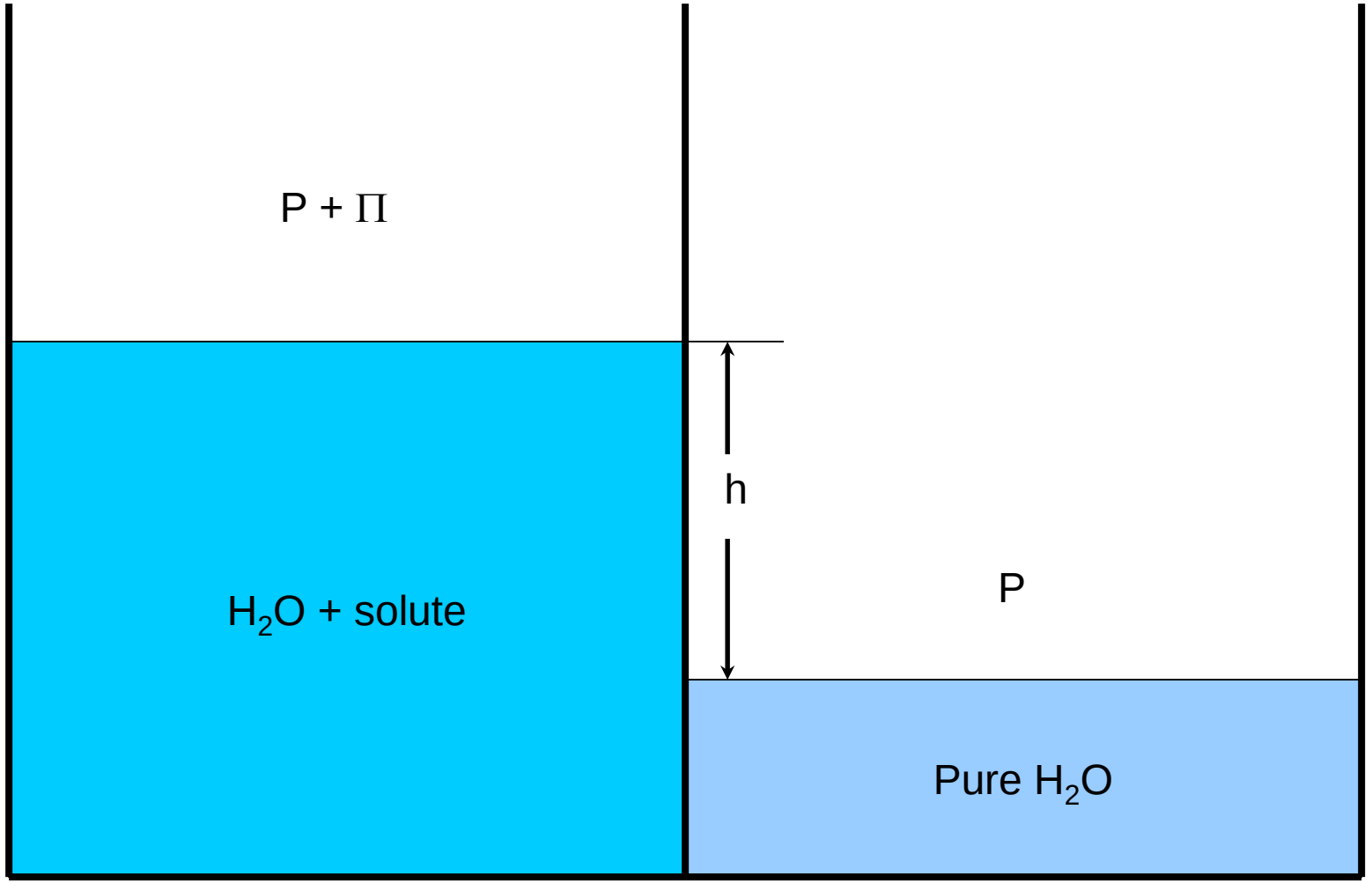
Osmotic Pressure

NC State University

Osmotic pressure arises from an imbalance in equilibrium state when solute is added to one compartment

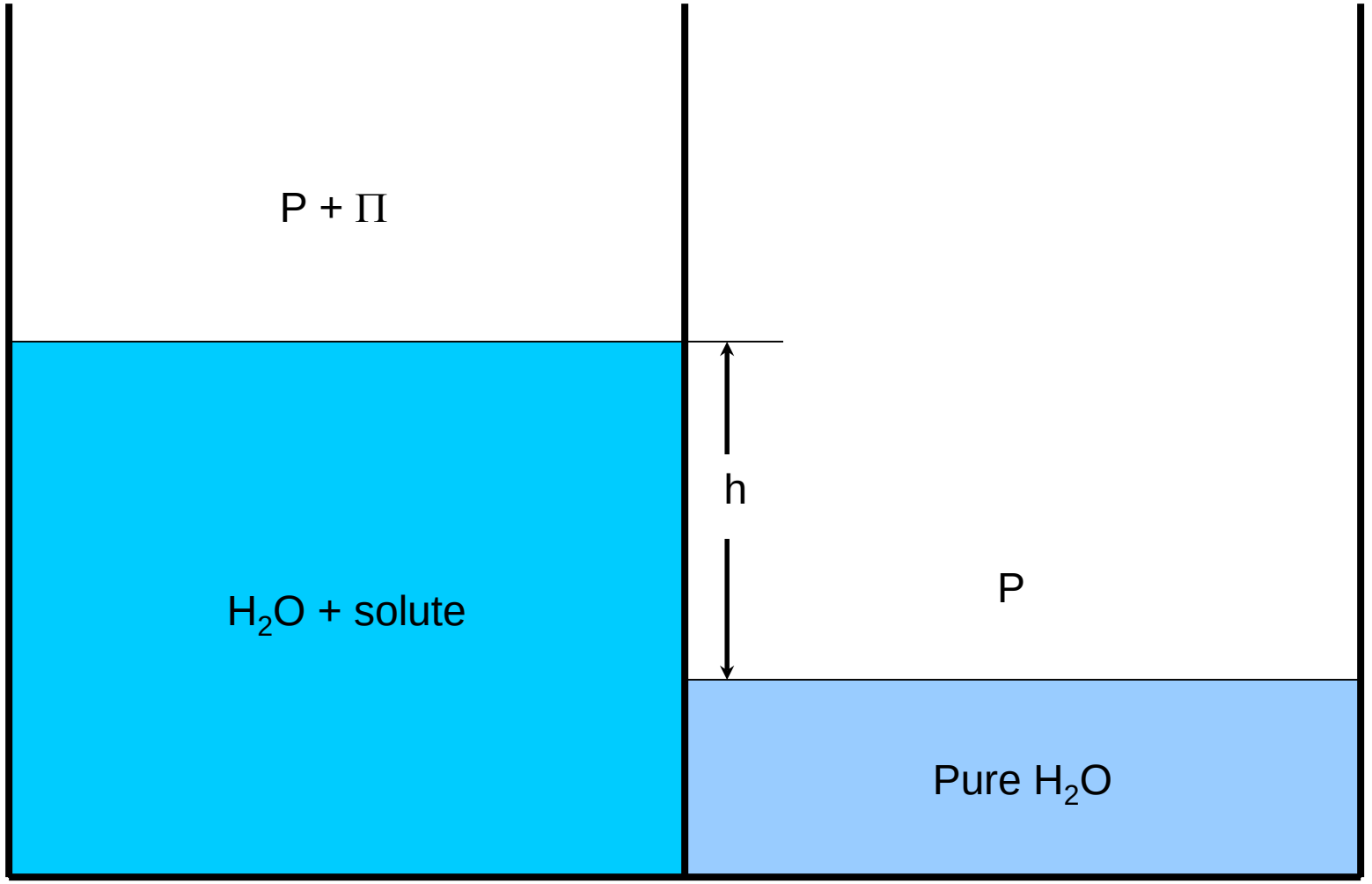


The flow of solvent leads to an increase in hydrostatic pressure



Hydrostatic pressure

$$\Pi = \rho g h$$



Osmotic pressure

Thus, we can compute the osmotic pressure from

$$\Pi V = n_2 RT$$

or

$$\Pi = cRT$$

where c is the molarity, n_2 expresses the number of moles of solute, and n_2/V, of the solution.
This equation is called the van't Hoff equation for osmotic pressure. The osmotic pressure can be used to determine the molecular masses of solutes, particularly solutes with large molecular masses such as polymers and proteins.

Question

What is the height of a column of water that will result from addition of enough NaCl to make a 0.1 M solution.

A. 25 m
B. 2.5 m
C 0.25 m
D 0.025 m

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$$\Pi = cRT = \rho g h$$

$$h = cRT/\rho g = \frac{(100\ mol/m^3)(8.31\ J/mol\text{–}K)(298\ K)}{(1000\ kg/m^3)(9.8\ m/s^2)}$$

$$= 25\ m$$

Use of osmotic pressure to determine molar mass

The van't Hoff equation can be modified to form used for the determination of molar mass by osmometry.

$$\Pi = cRT \qquad \Pi = \frac{wRT}{M_m}$$

Here we related to the concentration c in moles/liter to the concentration w in grams/liter and the molar mass M_m in grams/mole.

The experimental configuration uses the measurement of height as an estimate of the osmotic pressure. The equation $\Pi = \rho gh$ is used ($h = \Pi/\rho g$).

Use of osmotic pressure to determine molar mass

A sample of 1.5 mg. of a protein of unknown molar mass is added to an osmometer. The solution volume is 1 mL. The solution height increases by 1 cm. The measurement temperature is 298 K. What is the molar mass of the protein?

A. 37,900

B. 39,700

C. 79,300

D. 97,300

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$$M = \frac{wRT}{\Pi} = \frac{wRT}{\rho gh} = \frac{(1.5\ kg/m^3)(8.31\ J/mol\text{–}K)(298\ K)}{(1000\ kg/m^3)(9.8\ m/s^2)(0.01\ m)}$$

$$= 37.9\ kg\ /\ mol$$

$$= 37{,}900\ g\ /\ mol$$

How much energy is required to purify sea water?