Marks
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- The freezing point of a sample of seawater is measured as –2.15 °C at 1 atm pressure. Assuming that the concentrations of other solutes are negligible, and that the salt does not significantly change the density of the water from 1.00 kg L^{-1}, determine the concentration (in mol L^{-1}) of NaCl in this sample. (The molal freezing point depression constant for H_2O is 1.86 °C m^{-1})

The freezing point depression, ΔT_f, is given by,

$$\Delta T_f = K_f\, m$$

where K_f is the molal freezing point depression and m is the molality. The molality is the number of moles of particles dissolved in a kilogram of solvent.

If ΔT_f = 2.15 °C and K_f = 1.86 °C m^{-1}:

$$m = \Delta T_f / K_f = (2.15\ °C) / (1.86\ °C\ m^{-1}) = 1.156\ m^{-1} = 1.156\ mol\ kg^{-1}$$

A mole of NaCl dissolves to give two particles (Na^+ and Cl^-) so (1.156 / 2) mol = 0.578 mol of NaCl per kilogram of water is needed.

As the density of the solution is 1.00 kg L^{-1}, a kilogram of solution has a volume of one litre. Hence:

concentration required = 0.578 mol L^{-1}

Answer: **0.578 mol L^{-1}**

In principle, it would be possible to desalinate this water by pumping it into a cylindrical tower, and allowing gravity to push pure water through a semipermeable membrane at the bottom. At 25 °C, how high would the tower need to be for this to work? (The density of liquid Hg at 25 °C is 13.53 g cm^{-3}.)

The osmotic pressure, Π, is given by $\Pi = cRT$ where c is the concentration of the particles. From above, c = (2 × 0.578) mol L^{-1} and so:

$$\Pi = (2 \times 0.578\ mol\ L^{-1}) \times (0.08206\ atm\ L\ mol^{-1}\ K^{-1}) \times (298\ K) = 28.3\ atm$$

As 1 atm = 760 mmHg, this corresponds to (28.3 × 760) mmHg = 21500 mmHg.

Considering the relative densities of water and Hg, the height of water required to exert this pressure would be:

$$21500\ mmHg = (21500 \times \frac{13.53}{1.000})\ mmH_2O = 291000\ mmH_2O \text{ or } 291\ mH_2O.$$

The tower would need to be 291 m in height.

Answer: **291 m**