Marks
6

- Assume that NaCl is the only significant solute in seawater. A 1.000 L sample of seawater at 25 ºC and 1 atm has a mass of 1.0275 kg and contains 33.0 g of NaCl. At what temperature would this seawater freeze? The freezing point depression constant of water is 1.86 ºC kg mol^{-1}.

The formula mass of NaCl is 22.99 (Na) + 35.45 (Cl) = 58.44. Therefore, 33.0 g corresponds to:

$$\text{number of moles of NaCl} = \frac{\text{mass}}{\text{formula mass}} = \frac{33.0}{58.44} = 0.565 \text{ mol}$$

As each mole of NaCl dissolves to give 2 moles of particles (Na^+(aq) and Cl^-(aq)), the number of moles of solute is 2 × 0.565 = 1.129 mol.

If salt water contains only water and NaCl,

mass of water = 1.0275 – 0.0330 = 0.995 kg

Hence, the molality is

$$m = \frac{\text{moles of solute}}{\text{mass of solvent}} = \frac{1.129}{0.995} = 1.136 \text{ mol kg}^{-1}$$

The freezing point depression is then:

$$\Delta T_f = K_f\, m = 1.86 \times 1.136 = 2.11\ °C$$

As water normally freezes at 0°C, this saltwater will freeze at -2.11 °C.

Answer: **-2.11 °C**

ANSWER CONTINUES ON THE NEXT PAGE

The vapour pressure above pure H_2O is 23.76 mmHg at 25 ºC and 1 atm. Calculate the vapour pressure above this seawater under the same conditions.

The molar mass of H_2O is (2 × 1.008 (H)) + 16.00 (O) = 18.016. Therefore, 0.995 kg of water corresponds to

$$\text{moles of water} = \frac{\text{mass}}{\text{molar mass}} = \frac{(0.995 \times 10^3)}{18.016} = 55.3\,\text{mol}$$

As 1.129 mol of solute is also present, the mole fraction, X, of water is

$$X_{water} = \frac{\text{number of moles of water}}{\text{total number of moles}} = \frac{55.3}{(55.3 + 1.129)} = 0.980$$

From Raoult's law,

$$P_{water} = X_{water}P_{water}^{o} = 0.980 \times 23.76 = 23.3 \text{ mmHg}$$

Answer: **23.3 mmHg**

The desalination of seawater by reverse osmosis has been suggested as a way of alleviating water shortages in Sydney. What pressure (in Pa) would need to be applied to this seawater in order to force it through a semi-permeable membrane, yielding pure H_2O?

The concentration of solute is:

$$\text{concentration} = c = \frac{\text{number of moles of solute}}{\text{volume}} = \frac{1.129}{1.000} = 1.129\,\text{M}$$

The osmotic pressure, Π, required is given by

$$\Pi = cRT = (1.129) \times (0.08206) \times (25 + 273) = 27.6 \text{ atm}$$

As 1 atm = 101.3×10^3 Pa,

$$\Pi = 27.6 \times (101.3 \times 10^3) = 2800000 \text{ Pa} = 2.80 \times 10^6 \text{ Pa}$$

Answer: **2.80×10^6 Pa**