Colligative Properties

Name: KEY
Date:
Hour:

Introduction Question: Melting Ice

1. In colder climates during the winter, people put salt on the roads and walkways to melt ice. Why do people do this? Why does salt melt the ice?

Salt lowers the freezing pt of water so it will not freeze until lower temps. Salt water remains a liquid @ 0°C

Information: Dissociation and Total Molality of Particles

When you dissolve a solute in a solvent, the resulting solution has slightly different properties than the original solvent. For example, salt water has a different freezing point and boiling point than pure water. The salt interferes with water's ability to freeze and boil. A solution, therefore, will always have a *higher* boiling point and a *lower* freezing point than the pure solvent.

When ionic compounds dissolve, they dissociate. When an ionic compound dissociates that means that it breaks up into ions. For example, salt (sodium chloride) breaks up into sodium ions and chloride ions. This process is represented in the following balanced equation:

$$NaCl \rightarrow Na^+ + Cl^-$$

Note for the above equation that Cl^- does not need to be written as Cl_2 because Cl^- is a chloride ion and not a lone chlorine atom.

Since calcium nitrate is an ionic compound it also dissociates as shown below:

$$Ca(NO_3)_2 \rightarrow Ca^{2+} + 2\,NO_3^-$$

Covalent molecules do not dissociate. Although they may dissolve, they do not break up into ions.

Critical Thinking Questions

2. Write the balanced equation for the dissociation of magnesium chloride.

$MgCl_2 \rightarrow Mg^{2+} + 2Cl^-$

3. Write the balanced equation for the dissociation of ammonium sulfate.

$(NH_4)_2SO_4 \rightarrow 2NH_4^+ + SO_4^{2-}$

cut

Consider calcium nitrate. Each calcium nitrate breaks up into one calcium ion and two nitrate ions according to the balanced equation given in the information section. If you take one mole of calcium nitrate and put it in water, it will dissociate.

a) How many moles of calcium ions and how many moles of nitrate ions will there be in the solution?

One mole Ca^{2+} & 2 mols NO_3^-

b) What is the total number of moles of all ions in the solution?

3 ($1\,Ca^{2+} + 2\,NO_3^-$)

4 A solution is made so that it is 2.5 M $Ca(NO_3)_2$. Therefore the concentration of Ca^{2+} is 2.5 M and the concentration of NO_3^- is 5.0 M. The total concentration of all particles is 7.5 M. Explain.

$Ca(NO_3)_2 \rightarrow$ 1 mol Ca^{2+} so it = 2.5 M + 2 mol NO_3^- so it = 2(2.5 M) = 5.0 M } = 7.5 M

5 A solution is made so that the concentration is 3.0 m $MgCl_2$. What is the molality of Mg^{2+} and Cl^- ions? What is the total molality of all particles in the solution?

×2

Mg^{2+} 3.0 Cl^- 6.0 Total molality of all particles: 3+6 = 9.0 m

6 A solution is prepared by dissolving 45.7 g of sodium carbonate in 200 g of water.

a) What is the molality of the sodium carbonate?

$\frac{45.7\text{ g } Na_2CO_3}{1} \times \frac{1\text{ mol}}{106\text{ g}} = \frac{0.431\text{ mol}}{.200\text{ kg water}} = 2.16\text{ m}$

b) What is the total molality of all particles in the solution?

$Na_2CO_3 = 2Na^+ + 1CO_3^- = 3 \times 2.16\text{m} = 6.48\text{ m}$

7 Consider sugar ($C_6H_{12}O_6$), a covalent molecule. If a solution is made so that the concentration is 3.5 m in sugar, then what is the total molality of particles?

3.5 m b/c covalent

Information: Total Molality of Particles and Changes in Boiling/Freezing Points

You may be wondering how all of this ties together. We have seen that adding a solute changes the boiling and freezing points of solvents. The amount of the change depends on how much solute is added. Equations relating the change in boiling or freezing point and the molality is shown below:

$\Delta T_{bp} = (m_T)(K_{bp})$ for boiling point $\qquad \Delta T_{fp} = (m_T)(K_{fp})$ for freezing point

Note: m_T is the total molality of particles. K_{bp} and K_{fp} are constants called the molal boiling point elevation constant and the molal freezing point depression constant respectively. K_{bp} for water is 0.515 °C/m and K_{fp} for water is 1.853 °C/m.

decreases water's freezing pt or increases boiling pt.

Critical Thinking Questions

8 What is the freezing point of a 2.5 m solution of salt water. Hints: first find ΔT_{fp} and then subtract the change from the original freezing point (0°C for water). Also, remember m_T is not 2.5 m in this problem.

$NaCl \rightarrow 1Na^+ + 1Cl^-$ So 2 ions

$\Delta T_f = m_T \times K_f$

$= (2.5m \times 2)(1.853) = 9.3°C$ depresses (decreases) fpt.

$T_f = 0 - 9.3 = -9.3°C$

9 Find the boiling point of a 3.7 m solution of calcium chloride.

$CaCl_2 \rightarrow 1Ca^{2+} + 2Cl^- = 3$ ions

$\Delta T_b = m_T \times K_b$

$= (3.7m \times 3)(.515) = 5.72°C$ elevates (increases) bpt.

$T_b = 100 + 5.72 = 105.72°C$

10 What is the freezing point of a sugar solution in which the concentration of sugar is 2.25m? Note: sugar is covalent so it dissolves but it does not dissociate.

$T_f = m_T \times K_b$

$= (2.25 \times 1)(1.853) = 4.17°C$

$T_f = 0 - 4.17°C = -4.17°C$

Information: Raoult's Law

A solution will almost always have a lower vapor pressure than the pure solvent. For example, salt water will have a lower vapor pressure than pure water. The vapor pressure of a solution ($P_{solution}$) is related to the vapor pressure of the pure solvent ($P_{solvent}$) by the mole fraction of the solvent ($X_{solvent}$) in an equation known as Raoult's Law:

$$P_{solution} = (X_{solvent})(P_{solvent})$$

↑ mole fraction

Critical Thinking Questions

12. The vapor pressure of water at 20°C is 2.3 kPa. What is the vapor pressure of a solution formed by dissolving 21.5g of LiCl in 84.3g of H_2O at 20°C?

Need mole fraction first!

$\frac{21.5g\,LiCl}{1} \times \frac{1mol}{42.44g} = 0.507$ mol

$\frac{84.3g\,H_2O}{1} \times \frac{1mol}{18g} = 4.68$ mol

$P_{Soln} = (X_{solvent})(P_{solvent})$

$= \left(\frac{4.68}{4.68 + .507}\right) \times 2.3kPa$

$= .902 \times 2.3kPa$

$= 2.08kPa$

Skill Practice 40

Colligative Practice

Name: KEY

Date:

Hour:

5.25m 1. What is the molality of ammonium ions in a 1.75 m solution of $(NH_4)_3PO_4$?

$1.75 \times 3 = 5.25m$ (NH_4^+ ions)

7.0m 2. What is the total molality of particles in the ~~solution~~ in question 1?

1.75×4 total ions $= 7.0m$

1.75m 3. What is the total molality of particles in a 1.75 m solution of sugar (a covalent compound with the formula $C_6H_{12}O_6$)?

$1.75 \times 1 = 1.75m$ b/c sugar doesn't separate into ions

-6.95°C 4. Calculate the freezing point of a 0.75 m solution of $Al_2(CO_3)_3$. = 5 ions

$\Delta T_f = m_f \times K_f$ water's freezing pt constant

$= (.75m \times 5 ions)(1.853) = 6.95°C$ decreases normal fpt of 0°C

$T_f = 0 - 6.95°C = -6.95°C$

108.4°C 5. A solution is prepared by placing 72.8 g of calcium chloride in 120 g of water at 22°C. The vapor pressure of water at 22°C is 2.6 kPa.

a) What is the boiling point of the solution? need m_{CaCl_2}

$\frac{72.8g\,CaCl_2}{1} \times \frac{1mol}{111.1g} = .65$

$m = \frac{mol}{kg} = \frac{.655mol}{.120kg} = 5.$

$\Delta T_b = (5.46m \times 3)(.515) = 8.44°C$

$T_b = 100 + 8.44°C = 108.44°C$

-30.4°C b) What is the freezing point of the solution?

$\Delta T_f = (5.46 \times 3)(1.853) = 30.4°C$

$T_f = 0 - 30.4°C = -30.4°C$

$\frac{120g\,H_2O}{1} \times \frac{1mol}{18g} = 6.6$ m

~~2.4kPa~~ X c) What is the vapor pressure of the solution?

$P_{soln} = \left(\frac{6.67}{6.67 + .655}\right)(2.6kPa) = 2.36kPa$

6. A solution is prepared by placing 72.8 g of magnesium chloride in 120 g of water at 22°C.

109.8°C a) What is the boiling point of the solution?

$\frac{72.8g\,MgCl_2}{1} \times \frac{1mol}{95.3} = .764$

$\Delta T_b = \left(\frac{.764mol}{.120kg} \times 3\right)(0.515) = 9.84°C$

$T_b = 100 + 9.84 = 109.84°C$

-35.4°C b) What is the freezing point of the solution?

$\Delta T_f = \left(\frac{.764mol}{.120kg} \times 3\right)(1.853) = 35.4°C$

$T_f = 0 - 35.4°C = -35.4°C$