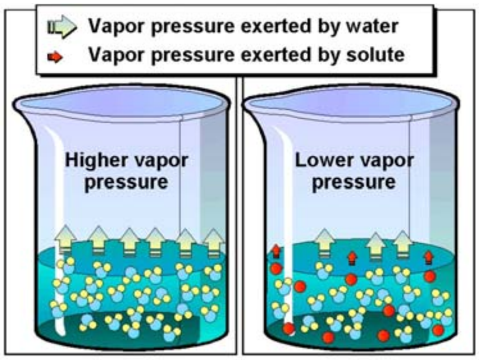
Understanding Colligative Properties

Dad misinterprets freezing point depression.

After a winter storm, people spread salt on the walks to help melt the ice. Salt reduces the freezing point of water. Actually, any soluble solute reduces the freezing point of water by interfering with crystallization. In this way, antifreeze keeps the water from freezing in an automobile radiator. This phenomenon is called **freezing point depression**. Antifreeze is left in the radiator during the summer. It also prevents the radiator from boiling over by raising the boiling point. Dissolved solute reduces the vapor pressure, raising the boiling point. This is called **boiling point elevation**.



The amount the freezing point is depressed or the boiling point is raised depends on the concentration of dissolved solute. The higher the concentration of dissolved solute is, the greater the effect on the boiling point or the freezing point is. Only the concentration of the particles of dissolved solute is important. The nature of the solute is not. A mole of dissolved sugar has exactly the same effect on the freezing point and boiling point of 1,000 g of water as a mole of antifreeze because it contains the same number of particles. Ionic compounds dissociate producing more particles per mole. One mole of dissolved sodium chloride, for example, produces one mole of aqueous sodium ions and one mole of aqueous chloride ions for a total of two moles [$NaCl(s) \rightarrow Na^+(aq) + Cl^-(aq)$]. One mole of dissolved sodium chloride, therefore, has twice the effect on the boiling and freezing points of 1,000 g of water as one mole of dissolved sugar. It is not the nature of the solute that matters, but only the concentration of dissolved particles that determines how large the change in freezing point or boiling point will be. Properties of a solution, such as this, which are dependent only on the number of particles in solution, and not on their nature are called **colligative properties.**

Answer the questions below based on your reading and on your knowledge of chemistry.

1. Why are boiling point elevation and freezing point depression considered colligative properties? ____________________

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2. Why is salt put on icy roads and sidewalks in the winter? ______________________________

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3. How will the boiling points of pure water and sea water compare? Why? ____________________

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Solve the following boiling point elevation problems and the freezing point depression problems as shown in the sample problems below. [*NOTE:* At standard pressure, 1 mol of dissolved particles will elevate the boiling point of 1,000 g of water by 0.52°C and will depress the freezing point of 1,000 g of water by 1.86°C]

Sample Problem

Find the boiling point of a solution containing 1,000 g of water and 2 mol of dissolved MgF_2.

Step 1: Determine the number of moles of solute particles
$2MgF_2(s) \rightarrow 2Mg^{2+}(aq) + 4F^{-}(aq)$ $mol = 6$

Step 2: Multiply the boiling point elevation per mole by the number of moles of solute to find the boiling point elevation
BPE = 0.52 °C/*mol* × 3 *mol* = 3.12°C

Step 3: Add the boiling point elevation to 100°C
BP = 100°C + 3.12°C = 10 3.12°C

Sample Problem

Find the freezing point of a solution containing 1,000 g of water and 30 g of dissolved antifreeze ($C_2H_4O_2$).

Step 1: Determine the number of moles of solute particles
C = 12 × 2 = 24
H = 1 × 4 = 4
O = 16 × 2 = 32
60

$$mol = \frac{g}{GFM} = \frac{30g}{60\,g/mol} = 0.5mol$$

Step 2: Multiply the freezing point depression per mole by the number of moles of solute to find the freezing point depression
FPD = 1.86 °C/*mol* × 0.5 *mol* = 0.93°C

Step 3: Subtract the freezing point depression from 0°C
FP = 0°C – 0.93°C = – 0.93°C

4. One mole of dissolved particles elevates the boiling point of 1,000 g of water by 0.52°C. At standard pressure, what will the boiling point of a solution be if it contains 1,000 g of water and:

a. 1 mol of antifreeze ($C_2H_4O_2$)? ________________
b. 1 mol of salt (NaCl)? ________________
c. 1 mol of ethanol (C_2H_5OH)? ________________
d. 2 mol of glycerol ($C_3H_6O_3$)? ________________
e. 2 mol of $CaCl_2(aq)$? ________________
f. 5 mol of sucrose ($C_{12}H_{22}O_{11}$)? ________________
g. 1 mol of $KNO_3(aq)$? ________________
h. 3 mol of $Ba(NO_3)_2(aq)$? ________________
i. 40 g of NaOH(*aq*)? ________________
j. 270 g of glucose ($C_6H_{12}O_6$)? ________________

5. One mole of dissolved particles depresses the freezing point of 1,000 g of water by1.86°C. At standard pressure, what will the freezing point of a solution be if it contains 1,000 g of water and:

a. 1 mol of glucose ($C_6H_{12}O_6$)? ________________
b. 1 mol of $BaCl_2(aq)$? ________________
c. 2 mol of methanol (CH_3OH)? ________________
d. 3 mol of glycerol ($C_3H_6O_3$)? ________________
e. 2 mol of $CuSO_4(aq)$? ________________
f. 4 mol of sucrose ($C_{12}H_{22}O_{11}$)? ________________
g. 3 mol of $KNO_3(aq)$? ________________
h. 2 mol of salt (NaCl)? ________________
i. 150 g of $KHCO_3(aq)$? ________________
j. 180 g of glucose ($C_6H_{12}O_6$)? ________________