ANSWERS TO COLLIGATIVE PROPERTIES

1. First, find how many moles of particles are produced in each solution:
   1 M KBr produces 2 mol,
   1 M $Al_2(SO_4)_3$ produces 5 mol,
   1 M table sugar produces 1 mol (since sugar is molecular),
   1 M $CaCl_2$ produces 3 mol, and
   2 M $MgCl_2$ produces 6 mol
   The more moles of particles in solution, the greater the VP depression, and since we want the least VP depression first the order is: table sugar, 1 M KBr, 1 M $CaCl_2$, 1 M $Al_2(SO_4)_3$, 2 M $MgCl_2$

2. Pure water has a greater VP than 1 M KCl, because the presence of a solute decreases the VP of water, and the greater the VP of a liquid the greater the evaporation rate (recall Unit III, Exercise 17).

3. Mixture B has the greater VP of ethanol because it has a greater ratio of moles ethanol to moles ethyl acetate and therefore has a VP closer to that of pure ethanol.

4. First, calculate the moles of ions in each solution. Since the volumes are all 100 mL, the concentration differences will depend only on the moles of particles and we will ignore the volumes.

   $$\text{KBr: moles of ions} = 10.0\text{ g KBr} \times \frac{1\text{ mol KBr}}{119.0\text{ g KBr}} \times \frac{2\text{ mol ions}}{1\text{ mol KBr}} = 0.168\text{ mol}$$

   $$\text{LiCl: moles of ions} = 10.0\text{ g LiCl} \times \frac{1\text{ mol LiCl}}{42.4\text{ g LiCl}} \times \frac{2\text{ mol ions}}{1\text{ mol LiCl}} = 0.472\text{ mol}$$

   $$Al_2(SO_4)_3\text{: moles of ions} = 10.0\text{ g } Al_2(SO_4)_3 \times \frac{1\text{ mol } Al_2(SO_4)_3}{342.3\text{ g } Al_2(SO_4)_3} \times \frac{5\text{ mol ions}}{1\text{ mol } Al_2(SO_4)_3} = 0.146\text{ mol}$$

   Arranging in order of highest to lowest VP means arranging from least to most moles of particles.
   Hence: $Al_2(SO_4)_3$, KBr, LiCl

5. Again, the volumes are the same so we just concern ourselves with the moles and mass:

   $$\text{moles of ions in } MgBr_2 = 23.0\text{ g } MgBr_2 \times \frac{1\text{ mol } MgBr_2}{184.1\text{ g } MgBr_2} \times \frac{3\text{ mol ions}}{1\text{ mol } MgBr_2} = 0.3748\text{ mol}$$

   $$\text{mass of NaBr} = 0.3748\text{ mol ions} \times \frac{1\text{ mol NaBr}}{2\text{ mol ions}} \times \frac{102.9\text{ g NaBr}}{1\text{ mol NaBr}} = \mathbf{19.3\text{ g}}$$

6. Sugar solution has a lower VP than pure water. As the water in the sugar solution slowly evaporates, the solution becomes more concentrated, the VP continues to drop, and the water in the remaining solution evaporates even more slowly. Eventually, the sugar solution is so concentrated that there is only a tiny amount of water present and the sugar solution just feels sticky.

7. Water boils at a lower temperature because the lowered atmospheric pressure requires a lower VP and hence a lower temperature for boiling to occur.

8. The boiling temperature will be more than $100^{o}C$ because there is more pressure from the atmosphere pressing down on the surface of the water, requiring a higher VP and higher temperature for boiling to occur.

9. The addition of a solute to the water in the radiator raises the boiling temperature of the water-antifreeze solution. Hence, the engine of the car can run at higher temperatures without having the radiator fluid boil.

10. First, find the moles of particles in 1 L of each solution:
    1 M KBr produces 2 mol ions, 2 M KBr produces 4 mol ions,
    1 M $Al_2(SO_4)_3$ produces 5 mol ions, 1 M table sugar produces 1 mol molecules,
    1 M $CaCl_2$ produces 3 mol ions, 2 M $MgCl_2$ produces 6 mol ions
    Since the more moles of solute particles, the lower the freezing temperature then arranging the solutions from highest (least moles) to lowest (most moles) freezing temperature gives:
    1 M table sugar, 1 M KBr, 1 M $CaCl_2$, 2 M KBr, 1 M $Al_2(SO_4)_3$, 2 M $MgCl_2$

11. First, calculate the moles of particles in each compound:

$$KCl: \text{moles of ions} = 20.0 \text{ g KCl} \times \frac{1 \text{ mol KCl}}{74.6 \text{ g KCl}} \times \frac{2 \text{ mol ions}}{1 \text{ mol KCl}} = 0.536 \text{ mol}$$

$$LiBr: \text{moles of ions} = 20.0 \text{ g LiBr} \times \frac{1 \text{ mol LiBr}}{86.8 \text{ g LiBr}} \times \frac{2 \text{ mol ions}}{1 \text{ mol LiBr}} = 0.461 \text{ mol}$$

$$Na_2SO_4: \text{moles of ions} = 20.0 \text{ g } Na_2SO_4 \times \frac{1 \text{ mol } Na_2SO_4}{142.1 \text{ g } Na_2SO_4} \times \frac{3 \text{ mol ions}}{1 \text{ mol } Na_2SO_4} = 0.422 \text{ mol}$$

The compound having the least moles of solute particles has the highest freezing temperature, so that in order of producing the highest to lowest freezing temperatures the solutions are:

Na_2SO_4, LiBr, KCl

12. The salt decreases the freezing temperature of water so that water on the roads remains liquid until the temperature drops well below zero Celcius. Because $MgCl_2$ produces 3 ions compared to 2 for NaCl, the freezing temperature will be lowered more for $MgCl_2$ than for NaCl and the water remains liquid to a lower temperature.

13. (a) First, calculate the concentration of particles in each solution:

$$NaCl: [\text{ions}] = 0.450 \frac{\text{mol NaCl}}{L} \times \frac{2 \text{ mol ions}}{1 \text{ mol NaCl}} = 0.900 \text{ M}$$

$$\text{Sucrose: [molecules]} = \frac{50.0 \text{ g}}{1.00 \text{ L}} \times \frac{1 \text{ mol}}{342.0 \text{ g}} = 0.146 \text{ M}$$

$$KCl: [\text{ions}] = \frac{50.0 \text{ g}}{1.00 \text{ L}} \times \frac{1 \text{ mol KCl}}{74.6 \text{ g}} \times \frac{2 \text{ mol ions}}{1 \text{ mol KCl}} = 1.34 \text{ M}$$

$$CO(NH_2)_2: [\text{molecules}] = \frac{100.0 \text{ g}}{1.00 \text{ L}} \times \frac{1 \text{ mol}}{60.0 \text{ g}} = 1.67 \text{ M}$$

$$MgCl_2: [\text{ions}] = \frac{25.0 \text{ g}}{1.00 \text{ L}} \times \frac{1 \text{ mol } MgCl_2}{95.3 \text{ g}} \times \frac{3 \text{ mol ions}}{1 \text{ mol } MgCl_2} = 0.787 \text{ M}$$

The urea test solution has the greatest concentration of particles, 1.67 M, and therefore creates the greatest osmotic pressure.

(b) The solutions having a net flow of water molecules from the 0.450 M NaCl side to the test solution side are the solutions having a smaller particle concentration than 0.900 M, that is, sucrose and $MgCl_2$.

14. The hypertonic solution has a greater solute particle concentration and therefore a lower water concentration than does the inside the bacterium. Therefore, water will pass preferentially from inside the bacterial cell to the jam, shrinking the bacterium and killing it from lack of internal water.

15. A hypotonic solution has a lower solute concentration and therefore a higher concentration of water than does the inside of a red blood cell. Hence, water passes preferentially from the surrounding solution into the red blood cell, causing the cell to swell and eventually burst.

16. Initial [ions] in side A $= 0.50 \frac{\text{mol NaCl}}{L} \times \frac{2 \text{ mol ions}}{1 \text{ mol NaCl}} = 1.0 \text{ M}$

Initial [ions] in side B $= 0.40 \frac{\text{mol } MgCl_2}{L} \times \frac{3 \text{ mol ions}}{1 \text{ mol } MgCl_2} = 1.2 \text{ M}$

Since side B has a greater concentration of ions and therefore a smaller concentration of water, water will pass preferentially through the membrane from side A to side B and after a day the water level in side B will be higher.