WorkSheet 3 Solutions

1. Let's look at the question "Does adding salt to water help the pasta cook faster?"
A. Beware of the internet as the source of all knowledge. Use your favorite search engine to try to answer this question to immerse yourself in the non-sense you'll find.
B. Clear your mind and let's think about it rationally.
How much salt should you add to pasta water. Recipes often say something like "salty like the ocean" For quantities, I've seen add 1-2 tablespoons to 4 quarts of water. Nice units.
Find the molality of this solution. (First you'll need the density of NaCl, then find the mass, then the number of moles...)
1 tablespoon NaCl has a mass of approximately 18g. MW of NaCl is 58.5 g/mol.
Therefore, 1 tablespoon salt = 0.308 mol NaCl
1 qt = 0.95 L, so 4 qt = 4*0.95L = 3.8 L water ~ 3.8 kg water
(density of water is about 1 g/mL)
molality (NaCl) = mols NaCl/ kg solvent = 0.308/3.8 = 0.081 molal
vant Hoff factor for NaCl = 2

Using the formula $\Delta T_b = imK_b = 2 * 0.081\ m * 0.5\ °C/m = 0.08°C$

If you prefer to absorb the van't Hoff factor into the molality, we have:
1 tablespoon salt = 0.308 mol NaCl = 0.308 mol Na^+ ion and 0.308 mols Cl^- ion
molality (solution) = (0.308 mols Na^+ + 0.308 mols Cl^-)/ 3.8 kg solvent = 0.16 molal

$\Delta T_b = mK_b = 0.16\ m * 0.5\ °C/m = 0.08\ °C$

You'll notice that it is very important to be careful when using these deceptively simple formulas. We advise for the student to choose a way to calculate molality (either using the van't Hoff factor or not) and stick with it. The form that includes that van't Hoff factor,i, is not as useful when there are multiple components dissolved in solution with different "i"s. This is seen in problem 4 in this worksheet.

What is the boiling point of this solution, given that Kb for water is 0.5 °C /m
100.08 Celsius

C. Do you think this would have any effect on the cooking rate? What else might it affect?
This addition of salt will have no noticeable effect on the cooking rate of the pasta.

2. Which has a lower Gibb's Free energy: 1 L of 1M NaCl solution and 1L of pure

water, or 2L of 0.5 M NaCl?

They will be the same; once the two 1L volumes are combined, the solutions are the same.

$$M_{solution\ one} = \left(\frac{1\ mol\ NaCl}{(1L + 1L)\ H_2O}\right) = 0.5\ M\ NaCl$$

$$M_{solution\ two} = \left(\frac{0.5 mol\ NaCl}{1L\ H_2O}\right) = 0.5\ M\ NaCl$$

3. You place 100 mL of a 0.1 M sucrose solution into a 1 L chamber along with 400 mL of a 0.2 M mL sucrose solution. You let the system come to equilibrium at a constant temperature of 25°C.
Given that the vapor pressure of pure water at 25°C is 23.76 Torr, what is the partial pressure of water in the vapor above the solutions at equilibrium?
(hint: What is the vapor pressure of the 0.1 M solution? What is the vapor pressure of the 0.2M solution? Can they have different vapor pressure? What will happen to the two solutions?)

First, calculate the mols of sucrose in each solution, as well as mols of water:
0.1 M * 0.1 L = 0.01 mol sucrose (solution 1)
0.2 M* 0.4 L = 0.08 mol sucrose (solution 2)
1L of water is 55.5 mols, so 0.1 L water = 5.55 mols and 0.4 L water = 22.22 mols

Raoult's Law: Psolvent= xP*solvent
where x is mol fraction and P* is the pure vapor pressure of the solvent

P(water soln1) = 5.55 mol water/(5.55+0.01) total mols * 23.76 Torr = 23.73 Torr
P(water soln2) = 22.22 mol water/(22.22+0.08) total mol *23.76 Torr = 23.67 Torr
The two solutions are completely miscible.

P (water, total mixed solution) = 27.77 mol water/(27.77+0.09) mols total*23.76 Torr = 23.68 Torr

The two solutions are completely miscible, so another way to think about the vapor pressure of the water after mixing the two sucrose solutions(the new solution volume is comprised of 20% solution 1 and 80% solution 2):
P (water, total mixed solution) = 0.2*23.73 Torr + 0.8*23.67 = 23.68 Torr

4. You dissolve 35 g of NaCl, 50 g of sucrose, and 50 g of $CaCl_2$ into 1 L of H_2O . What is the freezing point of this solution? What is its osmotic pressure at 298K?

Determine the number of mols of "stuff":
35g NaCl/58.5 g/mol = 0.6 mol NaCl = 0.6 mol Na^+ and 0.6 mol Cl^-
50g sucrose/343.3 g/mol = 0.146 mol sucrose (a non-electrolyte)
50 g of $CaCl_2$/111g/mol = 0.45 mol CaCl2 = 0.45 mol Ca^{2+} and 0.9 mol Cl^-
Total mols "stuff" = 0.6+0.6+0.146+0.45 + 0.9 = 2.7 mols total
Molality = 2.7 mol/1 kg water = 2.7 molal
ΔT = -1.86 °C/m * 2.7 m = -5.0 °C.
Thus, T_f = -5.0 °C.

Osmotic pressure:
Π=MRT
M = mols solute/L solution = 2.7 M (here we are assuming that the change in the volume of solution due to addition of the 3 solutes is negligible)
Π= (2.7mol/L) * (0.08206 Latm/Kmol)*(298K) = 66 atm

5. You are in the lab and trying to figure out the molecular weight of a sample of cellulose (a natural polymer). You make a sample in which you dissolve the cellulose in dimethylformamide at a concentration of 22 g/L. The osmotic pressure is found to be .00323 atm at 30°C. What is the molecular weight of the polymer?

Π=MRT, or Π=iMRT
It is simple here, because the van't Hoff factor is 1 for cellulose, a non-electrolyte.
M= Π/RT
= (0.00323 atm)/[(0.08206 Latm/Kmol)*(303.15K)] = 1.29 E-4 M
To obtain the molecular weight of cellulose polymer, divide the given density by the molarity, to gain the MW in units of grams/mol.
MW cellulose = (22g/L)/(1.29E-4 mol/L) = 1.7 E 5 gram/mol cellulose

6. What does osmotic pressure have to do with the following:
Salting food to preserve it. Any harmful bacteria on the meat will dehydrate, since water will flow out of the cell to try and lower the free energy and establish equilibrium. This extends the life of the food without need for refrigeration.
Keeping fish alive in a fish tank.
Some fish are salt-water fish, some are fresh-water fish.
If a salt-water fish is placed in fresh, purified water (meaning the concentration of electrolyte inside the fish cells is higher than in the aquarium water) water will enter the cells to try and establish an equilibrium. Fish cells can only contain a certain amount of pressure, and if too much water enters the cell, it will burst.

On the other hand, if a fresh-water fish is placed in salt water, water will exit the cells until the cells 'shrivel' up.

Given a person "saline" solution intravenously when they are dehydrated

Most dehydration in humans is "isotonic" dehydration, meaning cells are equally deficient in both water and electrolytes (typically sodium ion).
Typical saline solutions are essentially equal (in sodium) to the salt concentration in human blood.

Hypotonic dehydration occurs when sodium loss is greater than water loss and the osmotic pressure is greater inside the cells, which pulls more fluid out of the blood and into the cells.

Hypertonic dehydration occurs when water loss is greater than sodium loss
Higher blood sodium levels combined with decreased water inside cells increases the osmotic pressure in the bloodstream, which, in turn, pulls more fluid out of the cells.

7. In your car your radiator has a mixture of H_2O and ethylene glycol (anti-freeze). Ethylene Glycol has a boiling point of 197°C and a freezing point of -12.9°C.
Why do you use a mixture of water and ethylene glycol instead of pure ethylene glycol?
Ethylene glycol has a freezing point of -12.9°C. The addition of water to ethylene glycol will yield a solution that has a freezing point even lower than -12.9 and a boiling point even higher than 197 C.
To get the largest temperature range should you use a mixture that is more ethylene glycol or more water?

More ethylene glycol.