CHMG-142 in-class Name:____________________________

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$c_{H2O,\ liq}$ = 4.18 J/gK, c_{ice} = 2.09 J/gK, c_{steam} = 2.01 J/gK
Density of water = 0.9970 g/mL at 25 ºC
Density of water = 0.999 g/mL at 0 ºC
Density of ice = 0.9190 g/mL at 0 ºC
Density of liquid ethanol = 0.785 g/mL at 25 ºC
Density of solid ethanol = 0.83 g/mL at -120 ºC
1 foot=12 inches 1 inch = 2.54 cm 1 mL = 1 cm^3
ΔH_{fus} (H_2O) = 6.02 kJ/mol @ 0 ºC ΔH_{vap}(H_2O) = 40.7 kJ/mol @ 100 ºC

1 lb = 453.6 g

ΔH_{fus} (ethanol) = 4.93 kJ/mol @ −114.5ºC ΔH_{vap}(ethanol) = 38.56 kJ/mol @78.3ºC
$c_{ethanol,liq}$=2.4 J/gK
$c_{ethanol,\ gas}$ =1.4 J/gK
$c_{ethanol,\ solid}$ =1.3 J/gK
Normal boiling point of water =100ºC
Normal freezing point of water =0ºC
Normal boiling point of ethanol =78.3ºC

Normal freezing point of ethanol=−114.5ºC

[ethanol is C_2H_5OH]

K=ºC+273.15

K_f(ethanol)=$0.86\frac{°C}{m}$ K_f (water) = $1.86\frac{°C}{m}$
K_b(ethanol)=$0.43\frac{°C}{m}$ K_b (water) = $0.51\frac{°C}{m}$

Colligative properties are properties of a solution that depend only on the amount of solute present and NOT on the identity of the solvent. Colligative properties are **solvent properties.** If the solvent is water, then it is only the properties of water that matter. It makes no difference whether you add salt, sugar or gasoline to the water. It only matters how much solute you add.

Piece #1 (1/2 pt) I have 50.0 g of water. What is the freezing point of water?

273 K

Piece #2 (1/2 pt) I have 50.0 g of water. I add 1.0 g of ethanol (C_2H_5OH). What is the concentration of ethanol expressed as a % by mass?

$$\%\ by\ mass = \frac{g\ solute}{100\ g\ solution} = \frac{g\ solute}{g\ solution} \times 100$$

$$\frac{1.0\ g\ ethanol}{50.0\ g\ H_2O + 1.0\ g\ ethanol} \times 100 = 1.96\%\ by\ mass$$

Piece #3 (1/2 pt) I have 50.0 g of water. I add 1.0 g of ethanol (C_2H_5OH). What is the concentration of ethanol expressed as Molarity (M)?

$$\frac{mol\ solute}{L\ solution} = M$$

Well, I don't exactly know what the density of a 1.96% ethanol solution is…so I'm going with water: 0.997 g/mL at room temp.

$$1.0\ g\ C_2H_5OH \frac{1\ mol}{46.07\ g} = 0.0217\ mol\ ethanol$$

$$51.0\ g\ solution \frac{1\ mL}{0.997\ g} \frac{1\ L}{1000\ mL} = 0.0511\ L$$

$$\frac{0.0217\ mol\ ethanol}{.0511\ L\ solution} = 0.424\ M$$

Piece #4 (1/2 pt) I have 50.0 g of water. I add 1.0 g of ethanol (C_2H_5OH). What is the concentration of ethanol expressed as molality (m)?

$$molality = \frac{mol\ ethanol}{kg\ water} = \frac{0.0217\ mol\ ethanol}{0.050\ kg\ water} = 0.434\ m$$

Piece #5 (1/2 pt) I have 50.0 g of water. I add 1.0 g of ethanol (C_2H_5OH). What is the freezing point of the solution?

$$\Delta T_{freez} = T_{f,solution} - T_{f,solvent} = -K_f m$$

$$T_{f,solution} - 0℃ = -1.86\frac{℃}{m}(0.434\ m) = -0.807℃$$

$$T_{f,solution} -= -0.807℃ + 0℃ = -0.807℃$$

Piece #6 (1/2 pt) I have 50.0 g of ethanol. I add 1.0 g of water to it. What is the freezing point of the solution?

Now, ethanol is the solvent

$$1.0\ g\ H_2O \frac{1\ mol}{18.02\ g\ H_2O} = 0.05549\ mol\ H_2O$$

$$\frac{0.05549\ mol\ H_2O}{0.050\ kg\ ethanol} = 1.110\ m$$

$$\Delta T_{freez} = T_{f,solution} - T_{f,solvent} = -K_f m$$

$$T_{f,solution} - (-114.5\ ℃) = -0.86 \frac{℃}{m} (1.110\ m) = -0.954℃$$

$$T_{f,solution} -= -0.954℃ - 114.5℃ = 115.45℃$$

Puzzle #1 (2 pts) My driveway is 50 feet long and 10 feet wide. My driveway is coated in ice to an average depth of 1.2 inches. The current temperature is -5 °C. How much ethanol (g) would I need to throw on the driveway to have an ice free driveway?

UNITS! UNITS! UNITS!

I need to drop the freezing point of water to -5 °C or lower.

$$\Delta T_{freez} = T_{f,solution} - T_{f,solvent} = -K_f m$$

$$\Delta T_{freez} = (-5°C) - (0°C) = -5 = -(1.86\ \frac{°C}{m})m$$

$$m = 2.688\ m = \frac{2.688\ mol\ ethanol}{kg\ water}$$

$$50\ ft \frac{12\ in}{1\ ft} \frac{2.54\ cm}{1\ in} = 1524\ cm$$

$$1.2\ in \frac{2.54\ cm}{1\ in} = 3.048\ cm$$

$$10\ ft \frac{12\ in}{1\ ft} \frac{2.54\ cm}{1\ in} = 304.8\ cm$$

$$V = l \times w \times h = (1524\ cm)(3.048\ cm)(304.8\ cm) = 1.416 \times 10^6 cm^3 = 1.416 \times 10^6 mL$$

$$1.416 \times 10^6 mL \frac{0.919\ g}{mL} = 1.301 \times 10^6 g \frac{1\ kg}{1000\ g} = 1.301 \times 10^3 kg\ ice\ (water)$$

$$1.301 \times 10^3 kg\ ice\ (water) \frac{2.688\ mol\ ethanol}{kg\ water} = 3497\ mol\ ethanol \frac{46.07\ g}{mol} = 161{,}100\ g\ ethanol$$

Bonus Question #1 (2 pt) My driveway is 50 feet long and 10 feet wide. My driveway is coated in ice to an average depth of 1.2 inches. The current temperature is -5 ^oC. I don't have any ethanol, but I do have a fine Russian vodka which is 60 Proof. [A "proof" is 0.5% by mass. 200 proof = 100% ethanol, by mass].

How much vodka would I need to throw on my driveway to have an ice free driveway? [Think carefully…]

Did you think carefully…? ☺

I still start with

$$1.301 \times 10^3 kg\ ice\ (water)$$

I still need

$$m = 2.688\ m = \frac{2.688\ mol\ ethanol}{kg\ water}$$

But when I add the vodka rather than pure ethanol, I'm also adding water!!!

There's a couple ways you could do it.

It's something of a dilution problem where I'm actually diluting the vodka with the ice on the driveway! And it's kind of a "fun" little algebra problem!

$$moles\ needed\ on\ driveway = moles\ added\ from\ Vodka$$

If I'm using molality (mol/kg) instead of molarity(mol/L), it makes more sense to write it as:

$$m_{driveway} mass_{driveway} = m_{vodka} mass_{vodka}$$

Rather than the usual $M_1V_1=M_2V_2$

$$m_{vodka} = \frac{mol\ vodka}{kg\ water}$$

$$30\ proof = \frac{30\ g\ ethanol}{100\ g\ vodka} = \frac{30\ g\ ethanol}{70\ g\ water + 30\ g\ ethanol}$$

$$30\ g\ ethanol \frac{1\ mol}{46.07\ g} = 0.651\ mol\ ethanol$$

$$\frac{0.651\ mol\ ethanol}{0.070\ kg\ water} = 9.303\ m$$

$$m_{driveway} mass_{driveway} = m_{vodka} mass_{vodka}$$

$$(2.688\ m) mass_{driveway} = (9.303 m) mass_{vodka}$$

The "trick" to this is the $V_{driveway}$ because it is actually a combination of the initial amount of ice + V_{vodka}

$$(2.688\ m)(1.301 \times 10^3 kg\ ice\ (water) + mass_{vodka}) = (9.303 m) mass_{vodka}$$

I just need to solve for the mass of vodka

$$3497 + 2.688 mass = 9.303 mass$$
$$3497 = 6.615\ mass$$
$$528.6\ kg = mass$$

Now, if you think even more about this number, you'll realize why molality isn't normally used as a unit of measure. I need 528.6 kg of "vodka", but it's really the mass of the water in the vodka! [Molality = mol/kg solvent, so the mass I calculate is just that of the solvent.]

So, if I actually want something I can measure, I need the mass or volume of the mixture. It's 30% by mass ethanol, so I can easily get the total mass:

$$30\ \% = \frac{kg\ ethanol}{kg\ solution} \times 100 = \frac{kg\ ethanol}{(kg\ ethanol + kg\ water)} \times 100$$

$$0.30 = \frac{kg\ ethanol}{(kg\ ethanol + kg\ water)} = \frac{kg\ ethanol}{(kg\ ethanol + 528.6 kg\ water)}$$

Cross-multiply

$$0.30\ kg\ ethanol + 158.58 = kg\ ethanol$$
$$158.58 = 0.70\ kg\ ethanol$$

$$226.5\ kg\ ethanol$$
$$528.6\ kg\ water + 226.5\ kg\ ethanol = 755.1\ kg\ Vodka$$

Bonus Question #2 (0 pt) How many olives would I need to add to my “driveway martini”?

4.6 million…I like olives!