Name: Key Date: ______________ Mods: __________

Unit 13: Converting between Concentrations

Directions: _Setup solutions tables_ *to help you solve the following problems which require you to convert between various concentration terms.*

1. **Converting molality to molarity:**
What is the molarity of a 0.273 m aqueous solution of KCl? The density of the solution is 1.011 g/mL.

	Solute KCl	Solvent H_2O	solution
mols	0.273 ★		
grams	20.37	1000	1020.37
liters			1.009 ★

$0.273\,m = \frac{0.273 \text{ mols KCl}}{1 \text{ kg } H_2O}$

$\frac{0.273 \text{ mols KCl} \mid 74.6 \text{ g KCl}}{\mid 1 \text{ mol KCl}} = 20.37 \text{ g KCl}$

$D = \frac{m}{V}$ $1.011 \text{ g/mL} = \frac{1020.37 \text{ g sol'n}}{X \text{ mL sol'n}}$

$X = 1009 \text{ mL} = 1.009 \text{ L sol'n}$

$M = \frac{\text{mols solute}}{\text{L sol'n}} = \frac{0.273 \text{ mols}}{1.009 \text{ L}} = 0.271\,M$ KCl

2. **Converting molarity to molality:**
An aqueous solution is 0.907 M $Pb(NO_3)_2$. What is the molality of lead (II) nitrate in this solution? The density is 1.252 g/mL.

	solute $Pb(NO_3)_2$	solvent H_2O	solution
mols	0.907 ★		
grams	300.4	951.6 ★	1252
liters			1.0

$0.907\,M = \frac{0.907 \text{ mols } Pb(NO_3)_2}{1 \text{ L sol'n}}$

$\frac{0.907 \text{ mols } Pb(NO_3)_2 \mid 331.2 \text{ g } Pb(NO_3)_2}{\mid 1 \text{ mol } Pb(NO_3)_2} = 300.4 \text{ g } Pb(NO_3)_2$

$D = \frac{m}{V}$ $1.252 \text{ g/mL} = \frac{X \text{ g soln}}{1000 \text{ mL}}$

$X = 1252 \text{ g sol'n}$

$m = \frac{\text{mols solute}}{\text{kg solvent}} = \frac{0.907 \text{ mols}}{0.9516 \text{ kg}} = 0.953\,m$ $Pb(NO_3)_2$

3. **Converting mass percent to mole fraction:**
Calculate the mole fraction of NaCl in a 5% by mass aqueous solution of NaCl.

	solute NaCl	Solvent H_2O	solution
mols	0.085 ★	5.28	5.365 ★
grams	5	95	100
liters			

$5\% = \frac{5 \text{ g NaCl}}{100 \text{ g sol'n}}$

$\frac{5 \text{ g NaCl} \mid 1 \text{ mol NaCl}}{\mid 58.5 \text{ g NaCl}} = 0.085 \text{ mols NaCl}$

$\frac{95 \text{ g } H_2O \mid 1 \text{ mol } H_2O}{\mid 18 \text{ g } H_2O} = 5.28 \text{ mols } H_2O$

$X_{NaCl} = \frac{\text{mols NaCl}}{\text{mols sol'n}} = \frac{0.085}{5.365} = 0.016$ NaCl

4. **Converting mass percent to molarity:**
Reagent grade concentrated aqueous ammonia is 27% by mass NH_3 and has a density of 0.90 g/mL. What is the molarity of this solution?

	solute NH_3	solvent H_2O	solution
mols	1.59 *		
grams	27		100
liters			0.111 *

$27\% = \frac{27\ g\ NH_3}{100\ g\ sol'n}$

$\frac{27\ \cancel{g\ NH_3}}{} \Big| \frac{1\ mol\ NH_3}{17\ \cancel{g\ NH_3}} = 1.59\ mols\ NH_3$

$D = \frac{m}{V}$ $\left\{ 0.90\ g/mL = \frac{100\ g\ sol'n}{x\ mL\ sol'n} \right.$

$X = 111\ mL = 0.111\ L\ sol'n$

$M = \frac{mols\ solute}{L\ sol'n} = \frac{1.59\ mols}{0.111\ L} = 14.32\ M\ NH_3$

5. **Converting mole fraction to molality:**
If the mole fraction of Na_2CO_3 is 0.0340 in an aqueous solution, what is the molality of the solution?

	Solute Na_2CO_3	solvent H_2O	Solution
mols	0.0340*	0.966	1
grams		17.39 *	
liters			

$X_{Na_2CO_3} = 0.0340 = \frac{0.0340\ mols\ Na_2CO_3}{1\ mol\ sol'n}$

$\frac{0.966\ \cancel{mols\ H_2O}}{} \Big| \frac{18\ g\ H_2O}{1\ \cancel{mol\ H_2O}} = 17.39\ g\ H_2O$

$m = \frac{mols\ solute}{kg\ solvent.} = \frac{0.0340\ mols}{0.01739\ kg} = 1.96\ m\ Na_2CO_3$

6. **Converting mass percent to molality:**
What is the molality of a 4.50% by mass aqueous NaOH solution?

	solute NaOH	solvent H_2O	solution
mols	0.1125 *		
grams	4.50	95.5 *	100
liters			

$4.50\% = \frac{4.50\ g\ NaOH}{100\ g\ sol'n}$

$\frac{4.50\ \cancel{g\ NaOH}}{} \Big| \frac{1\ mol\ NaOH}{40\ \cancel{g\ NaOH}} = 0.1125\ mol\ NaOH$

$m = \frac{mols\ solute}{kg\ solvent} = \frac{0.1125\ mols}{0.0955\ kg} = 1.18\ m\ KOH$

7. Write the **definition** (aka: formula) of each concentration in terms of **solute**, **solvent**, and/or **solution**:

molarity (M)	molality (m)	mole fraction (X)	mass percent (%)
$\frac{\text{mols solute}}{\text{L solution}}$	$\frac{\text{mols solute}}{\text{kg solvent}}$	$\frac{\text{mols solute}}{\text{mols solution}}$	$\frac{\text{mass solute}}{\text{mass solution}}$

8. Assume you dissolve 2.56 g of malic acid, $C_4H_6O_5$, in half a liter of water (500.0 g). The density of the solution is equivalent to that of water, 1.0 g/mL.

$$\frac{2.56 \text{ g } C_4H_6O_5}{} \left| \frac{1 \text{ mol } C_4H_6O_5}{134 \text{ g } C_4H_6O_5} \right. = 0.019 \text{ mol } C_4H_6O_5$$

Solutions Table:

	solute $C_4H_6O_5$	solvent H_2O	solution
mols	0.019	27.78	
grams	2.56	500	502.56
liters		0.5	0.50256

$$\frac{500 \text{ g } H_2O}{} \left| \frac{1 \text{ mol } H_2O}{18 \text{ g } H_2O} \right. = 27.78 \text{ mol } H_2O$$

$$D = \frac{m}{V} \quad \frac{1.0}{\text{g/mL}} = \frac{502.56 \text{ g soln}}{X \text{ mL soln}}$$

$$X = 502.56 \text{ mL} = 0.50256 \text{ L soln}$$

a) Calculate the <u>molarity</u> of this solution:

$$M = \frac{\text{mols solute}}{\text{L soln}} = \frac{0.019 \text{ mols}}{0.50256 \text{ L}} = 0.038 \text{ M } C_4H_6O_5$$

b) Calculate the <u>molality</u> of this solution:

$$m = \frac{\text{mols solute}}{\text{kg solvent}} = \frac{0.019 \text{ mols}}{0.50 \text{ kg}} = 0.038 \text{ m } C_4H_6O_5$$

c) Calculate the <u>mole fraction</u> of $C_4H_6O_5$ in this solution:

$$X_{C_4H_6O_5} = \frac{\text{mols solute}}{\text{mols sol'n}} = \frac{0.019 \text{ mols}}{27.80 \text{ mols}} = 6.83 \times 10^{-4} \ C_4H_6O_5$$

d) Calculate the <u>mass percent</u> of $C_4H_6O_5$ in this solution:

$$\% \text{ mass} = \frac{\text{g solute}}{\text{g soln}} \times 100 = \frac{2.56 \text{ g}}{502.56 \text{ g}} \times 100 = 0.509 \% \ C_4H_6O_5$$

9. Given the info filled in the table below, set up three different solution tables (one for each compound), and solve to fill in the blanks in the table below.

Aqueous Solution of:	Molality	Mass Percent	Mole Fraction
NaI	0.15	2.20%	0.0027
C_2H_5OH	1.15	5.0	0.020
$C_{12}H_{22}O_{11}$	3.80	56.50%	0.064

NaI:

	solute NaI	solvent H_2O	solution
mols	0.15 *	55.56	55.71 *
grams	22.49 *	1000	1022.49 *
liters			

$0.15\ m = \frac{0.15 \text{ mols solute}}{1 \text{ kg solution}}$

$\frac{0.15 \cancel{\text{mols NaI}} \mid 149.9 \text{ g NaI}}{1 \cancel{\text{mol NaI}}} = 22.49 \text{ g NaI}$

$\frac{1000 \cancel{\text{g } H_2O} \mid 1 \text{ mol } H_2O}{18 \cancel{\text{g } H_2O}} = 55.56 \text{ mol } H_2O$

$\%\text{ mass} = \frac{\text{g solute}}{\text{g solution}} \times 100 = \frac{22.49\text{ g}}{1022.49\text{ g}} \times 100 = 2.20\%$ NaI

$X_{NaI} = \frac{\text{mols solute}}{\text{mols solution}} = \frac{0.15}{55.71} = 0.0027$ NaI

C_2H_5OH:

	solute C_2H_5OH	solvent H_2O	solution
mols	0.109 *	5.28	5.39 *
grams	5	95 *	100
liters			

$5\% = \frac{5\text{ g solute}}{100 \text{ solution}}$

$\frac{5 \cancel{\text{g } C_2H_5OH} \mid 1 \text{ mol } C_2H_5OH}{46 \cancel{\text{g } C_2H_5OH}} = 0.109 \text{ mol } C_2H_5OH$

$\frac{95 \cancel{\text{g } H_2O} \mid 1 \text{ mol } H_2O}{18 \cancel{\text{g } H_2O}} = 5.28 \text{ mol } H_2O$

$m = \frac{\text{mols solute}}{\text{kg solvent}} = \frac{0.109 \text{ mols}}{0.095 \text{ kg}} = 1.15\ m$ C_2H_5OH

$X_{C_2H_5OH} = \frac{\text{mols solute}}{\text{mols sol'n}} = \frac{0.109 \text{ mols}}{5.39 \text{ mols}}$ 0.020 C_2H_5OH

$C_{12}H_{22}O_{11}$:

	solute $C_{12}H_{22}O_{11}$	solvent H_2O	solution
mols	0.064 *	0.936	1
grams	21.89 *	16.85 *	38.74 *
liters			

$0.064 = \frac{0.064 \text{ mols solute}}{1 \text{ mol solution}}$

$\frac{0.064 \cancel{\text{mols } C_{12}H_{22}O_{11}} \mid 342 \text{ g } C_{12}H_{22}O_{11}}{1 \cancel{\text{mol } C_{12}H_{22}O_{11}}} = 21.89 \text{ g } C_{12}H_{22}O_{11}$

$\frac{0.936 \cancel{\text{mols } H_2O} \mid 18 \text{ g } H_2O}{1 \cancel{\text{mol } H_2O}} = 16.85 \text{ g } H_2O$

$m = \frac{\text{mols solute}}{\text{kg solvent}} = \frac{0.064 \text{ mols}}{0.01685 \text{ kg}} = 3.8\ m\ C_{12}H_{22}O_{11}$

$\%\text{ mass} = \frac{\text{g solute}}{\text{g solution}} \times 100 = \frac{21.89\text{ g}}{38.74} \times 100 = 56.50\%\ C_{12}H_{22}O_{11}$