Recitation Worksheet Six

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Textbook:

Chemistry & Chemical Reactivity
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Instructions:

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  - Answers must be written in the corresponding answer boxes.
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- This worksheet is due no later than **12:00 PM (noon) on the Saturday, October 4th.**
- A periodic table and formula sheet are attached to the end of this worksheet. Please keep these attached to your worksheet in the correct order when submitting to Gradescope.

molar mass of benzene = 78.12 g/mol molar mass of toluene = 92.15 g/mol

1. What is the *total* vapor pressure of a solution obtained by mixing 35.8 g of benzene (C_6H_6, a **volatile solute**) in 56.7 g toluene ($C_6H_5CH_3$) **solvent** at 25 °C. The vapor pressure of pure benzene is 95.1 mmHg, and the vapor pressure of pure toluene is 28.4 mmHg at 25 °C.

$\boxed{56.9}$ mmHg

If both the solute & solvent are volatile ∴ the total vapor pressure is sum of the vapor pressures of benzene & toluene

* Note: both benzene & toluene have similar IMFs (dispersion forces).

In this case the mixture of benzene & toluene is considered ideal

$$P_{tot} = P_{benzene} + P_{toluene} = X_{benzene} P^{\circ}_{benzene} + X_{toluene} P^{\circ}_{toluene}$$

$$n_{benzene} = 35.8g \times \frac{1 \text{ mol}}{78.12g} = 0.4582693292$$

$$n_{toluene} = 56.7g \times \frac{1 \text{ mol}}{92.15g} = 0.6153011394$$

○ $X_{benzene} = \dfrac{n_{benzene}}{n_{benzene} + n_{toluene}}$

$= \dfrac{0.4582693292}{0.4582693292 + 0.6153011394}$

$= 0.4268646937 \text{ mol}$

○ $X_{toluene} = 1 - 0.4268646937 = 0.5731353063 \text{ mol}$

∴ $P_{tot} = (95.1 \times 0.4268646937) + (28.4 \times 0.5731353063) = 56.87187507$

~ 56.9 mmHg

2. Calculate the vapor pressure at 25 °C of a solution containing 165 g of glucose, $C_6H_{12}O_6$, **non-volatile solute** dissolved in 685 g of water. The vapor pressure of pure water is 23.8 mmHg at 25 °C.

$\boxed{23.2}$ mmHg

molar mass of glucose = 180.18 g/mol molar mass of H_2O = 18.02 g/mol

$$P_{solution} = X_{H_2O} \times P^{\circ}_{H_2O}$$

$$X_{H_2O} = \frac{n_{H_2O}}{n_{H_2O} + n_{C_6H_{12}O_6}} = \frac{38.01331853}{38.01331853 + 0.9157509158}$$

$$= 0.9764764242$$

$$n_{H_2O} = 685g \times \frac{1 \text{ mol}}{18.02g} = 38.01331853 \text{ mol}$$

$$n_{C_6H_{12}O_6} = 165g \times \frac{1 \text{ mol}}{180.18g} = 0.9157509158$$

∴ $P_{solution} = 0.9764764242 \times 23.8 \text{ mmHg} = 23.2401389 \text{ mmHg}$

~ 23.2 mmHg

2

3. Dissolving 1.10 g of an unknown compound in 75.22 g of benzene reduces its freezing point from 5.53 °C to 4.92 °C. What is the molar mass of the unknown compound? K_f benzene = −5.12 °C.

123 g/mol

$$\Delta T_f = -K_f \times m \times i = -K_f \times \frac{mol\ of\ solute}{kg\ of\ solvent} \times i$$

** molar mass (g/mol) = $\frac{grams\ of\ solute}{mol\ of\ solute}$ **

given (in the question)

mol of solute is determined from ΔT_b equation

$$\Delta T_f = (T_{solution} - T_{solvent}) = -K_f \times \frac{mol\ of\ solute}{kg\ of\ solvent} \times i$$

$$(4.92 - 5.53)°C = -5.12°C \times \frac{mol\ of\ solute}{75.22g \times \frac{1kg}{1000g}} \times 1 \Rightarrow \therefore mol\ of\ solute = 8.961757812 \times 10^{-3} mol$$

$$\therefore molar\ mass\ of\ unknown\ compound = \frac{1.10g}{8.961757812 \times 10^{-3} mol} =$$

$$122.7437767\ g/mol$$
$$\sim 123 g/mol$$

4. If the freezing point depression of a 0.10 m **aqueous** solution of a solute can be expressed as $\Delta T_f = -i0.186$ °C. For the group of solutes given, which freezing points **correctly** matches the solutes dissolved in water? K_f for H_2O = −0.186 °C/m

D

A. CH_3CH_2OH, $\Delta T_f = -0.930$ °C
B. $MgSO_4$, $\Delta T_f = -0.186$ °C
C. NH_4NO_3, $\Delta T_f = -0.774$ °C
D. $CaCl_2$, $\Delta T_f = -0.558$ °C
E. C_6H_6, $\Delta T_f = -0.297$ °C

Strategy:
- to determine which freezing point correctly matches you have to determine the Van't Hoff factor for each compound

$$-\Delta T_f = K_f \times m \times i = -0.186\frac{°C}{m} \times 0.10m \times i$$
$$= -i0.0186°C$$

Ⓐ CH_3CH_2OH (molecular) $\therefore i = 1$ $\therefore \Delta T_f = 1 \times -0.186°C$
$= -0.186°C$

Ⓑ $Mg SO_4 (s) \rightleftharpoons Mg^{2+}_{(aq)} + SO_4^{2-}_{(aq)}$ $i = 2$ $\therefore \Delta T_f = 2 \times -0.186°C$
$= -0.372°C$

Ⓒ $NH_4 NO_3 (s) \rightleftharpoons NH_4^+_{(aq)} + NO_3^-_{(aq)}$ $i = 2$ $\therefore \Delta T_f = -0.372°C$

Ⓓ $CaCl_2 (s) \rightleftharpoons Ca^{2+}_{(aq)} + 2 Cl^-_{(aq)}$ $i = 3$ $\therefore \Delta T_f = -0.558°C$

Ⓔ C_6H_6 (molecular) $\therefore i = 1$ $\therefore \Delta T_f = -0.186°C$

5. Substance A has a **greater molar mass** than substance B. They are both <u>nonvolatile</u> and <u>nonelectrolyte</u>. If 10 g of substance A are completely dissolved in 250 g of water in one beaker (solution A), and 10 g of substance B are completely dissolved in 250 g of water in another beaker (solution B), then *vapor pressure of solution B is higher*

D

   A. the vapor pressure of solution A will be lower than the <u>vapor pressure of solution B.</u>
   B. the solution of A will freeze at a lower temperature than the solution of B. *B will freeze at a lower temp.*
   C. the two solutions will have the same vapor pressure. *VP of A > VP of B*
   (D.) the boiling point of solution A will be lower than the boiling point of solution B.
   E. the solution of A will have a higher osmotic pressure than the solution of B. *B will have a higher osmotic pressure*

- colligative properties are related to the number of solute particles expressed in mol (↑ in mol of solute ↓vapor pressure ↓ freezing point ↑boiling point ↑Osmotic pressure)

- moles = mass of solute / molar mass of solute → if solutes A & B have the same mass → if solute A has a greater molar mass than B → the mols of A are FEWER than mol of B

6. We wish to lower the freezing point of the water in an automobile radiator to −40 °C. The total mass of water in radiator is 12.0 kg. <mark>For which one of the following compounds would we have to use the **greatest** mass of solute</mark> to achieve the same degree of freezing points depression? You may assume that K_f for water = −1.86 °C/m and that all ionizable solutes are completely ionized.

D

   A. AlF_3 *i=4*   (M.W. = 84 g/mol)
   B. C_2H_5OH. *i=1*   (M.W. = 46 g/mol)
   C. $CaCl_2$ *i=3*   (M.W. = 111 g/mol)
   (D) $C_3H_6(OH)_2$ *i=1* (M.W. = 76 g/mol)
   E. $NaCl$ *i=2*   (M.W. = 58.5 g/mol)

A) AlF_3

$$\Delta T_f = -K_f \times m \times i$$

$$-40 - 0\,°C = -1.86\,\frac{°C}{m} \times \frac{mol}{12.0\,kg} \times 4$$

$$mol = 64.516$$

$$Mass = 64.516\,mol \times \frac{84\,g}{mol} = 5419\,g$$

B) C_2H_5OH
$$mass = 11871\,g$$

c) $CaCl_2$
$$Mass = 9548\,g$$

D) $C_3H_6(OH)_2$ } *Greatest mass*
$$mass = 19\,613\,g$$

E) $NaCl$
$$mass = 629\,g$$

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7. What is the vapor pressure at 20 °C of a saturated solution of urea ($CO(NH_2)_2$), a non-volatile solute in methanol (CH_3OH) if the solubility of urea is 17.0 g urea/100 mL methanol? The density of methanol is 0.792 g/mL, and its vapor pressure at 20 °C is 95.7 mmHg.

85.9 mmHg

① Mass of methanol $= 100\,mL \times \dfrac{0.792g}{1mL} = 79.2g$

↑ molarity = ↑ osmotic pressure

② Molar mass of $CO(NH_2)_2 = 60.07\,g/mol$ Molar mass of $CH_3OH = 32.05\,g/mol$

$n\,CO(NH_2)_2 = 17.0g \times \dfrac{1mol}{60.07g} = 0.283003163\,mol$

$n_{CH_3OH} = 79.2g \times \dfrac{1mol}{32.05g} = 2.471138846$

③ $X_{CH_3OH} = \dfrac{2.471138846}{2.471138846 + 0.283003163\,mol}$
$= 0.8972445277$

④ $P_{solution} = X_{CH_3OH} \times P^0_{CH_3OH}$
$= 0.8972445277 \times 95.7$
$= 85.8668013\,mmHg$
$\sim 85.9\,mmHg$

8. What mass of NaCl in grams should be added to a 2.50 L of water in an ice-cream maker to make a solution that freezes at -10.0 °C?

393 g

① $\Delta T_f = T_f\,(solution) - T_f\,(solvent) = -k_f \times m \times i$

$-10.0°C - 0°C = -1.86°C/m \times \dfrac{mol\ of\ NaCl}{2.50L \times \dfrac{1000mL}{1L} \times \dfrac{1g}{1mL} \times \dfrac{1kg}{1000g}} \times 2$

$-10.0°C = -1.488 \times mol\ of\ NaCl$

$\therefore mol\ of\ NaCl = 6.720430108\,mol$

② Grams of NaCl $= 6.720430108\,mol\ of\ NaCl \times \dfrac{58.44g\ NaCl}{1\,mol\ NaCl}$
$= 392.7419555g$
$\sim 393g$

9. An ideal liquid solution has two volatile components (a volatile solute dissolved in a volatile solvent). In the vapor in equilibrium with the solution, the **mole fractions** of the components are:

C

   A. Both equal to 0.5
   B. Equal but not necessarily 0.5
   C. Not very likely to be equal
   D. 1.0 for the solvent and 0.0 for the solute

From the information provided in the question, nothing suggests that the conc. of the two volatile species are the same

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10. Some of us assume that adding salt to pasta water before boiling it helps with the cooking process by raising the boiling point of water. How many grams of table salt (NaCl, molar mass = 58.44 g/mol) would be added to 1L of water at 760 torr to raise the boiling point of water by 2.0 °C? K_b for H_2O = 0.512 °C/m.

$\boxed{110}$ g

① $\Delta T_b = K_b \times m \times i$

$2.0°C = 0.512 \frac{°C}{m} \times \frac{mol\ of\ NaCl}{1kg\ of\ H_2O} \times 2$

∴ mol of NaCl = 1.953125 mol

② Mass of NaCl required to raise the temperature of 1L of H_2O by 2.0°C

$1.953125\ mol\ NaCl \times \frac{58.44g\ NaCl}{mol\ NaCl}$

$= 114.140625 g$

$\sim 110\ g$

11. An unknown compound is 42.9 % C, 2.4% H, 16.7% N, and 38.1% O by mass. Dissolving 6.45 g of this unknown compound in 50.0 mL of benzene (density of benzene = 0.879 g/mL), lowers the freezing point of benzene from 5.53 °C to 1.37 °C. What is the molecular formula of this compound? K_f for benzene = 5.12 °C/m _Formatting tip:_ the elements in your answer should follow this order: $C_wH_xN_yO_z$.

$\boxed{C_6H_4N_2O_4}$

① Determine the empirical formula of the compound

$C = 42.9g \times \frac{1mol}{12.01} = 3.572023314$

$H = 2.4g \times \frac{1mol}{1.01} = 2.376237624$ Divide by the

$N = 16.7g \times \frac{1mol}{14.01g} = 1.192000571$ least no. of moles (1.192000571)

$O = 38.1g \times \frac{1mol}{16.00g} = 2.38125$

∴ #C $= \frac{3.572023314}{1.192000571} = 2.996649499 \sim 3$

#H $= \frac{2.376237624}{1.192000571} = 1.99347839 \sim 2$

#N = 1

#O $= \frac{2.38125}{1.192000571} = 1.997683384 \sim 2$

Empirical formula = $C_3H_2NO_2$

② Determine the molecular formula of the compound

$\Delta T_f = -K_f \times m \times i$

Tf solution − Tf solvent = $-k_f \times m \times i$

$(1.37 - 5.53)°C = -5.12 \frac{°C}{m} \times \frac{mol\ of\ solute}{50.0mL \times 0.879\frac{g}{mL} \times \frac{1kg}{1000g}} \times 1$

∴ mol of solute = 0.035709375 mol

Molar mass of molecular formula =

$\frac{6.45g}{0.035709375\ mol} = 180.6248359\ g/mol$

③ Molecular formula =

Empirical formula $\times \frac{molar\ mass\ of\ molecular\ formula}{molar\ mass\ of\ empirical\ formula}$

$= C_3H_2NO_2 \times \frac{180.6248359}{84.06}$

$= (C_3H_2NO_2) \times 2 = C_6H_4N_2O_4$

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12. Which of the following will have the **lowest** boiling point?

[C]

A. 0.25 *m* aqueous sucrose — molecular $(C_{12}H_{22}O_{11})$ ∴ $i = 1 \times 0.25 \frac{mol}{} = 0.25$ mol particles

B. 0.50 *m* aqueous glucose — molecular $(C_6H_{12}O_6)$ $i = 1 \times 0.50$ mol $= 0.50$ mol particle

C. Pure water $i = 1$ ⟵ circled

D. 0.05 *m* aqueous FeI_3 — ionic $FeI_3 (s) \xrightarrow{H_2O} Fe^{3+}(aq) + 3I^-(aq)$ ∴ $i = 4 \times 0.05$ mol $= 0.2$ mol particles

E. 0.1 *m* aqueous $SrSO_4$ — ionic $SrSO_4(s) \xrightarrow{H_2O} Sr^{2+}(aq) + SO_4^{2-}(aq)$ $i = 2 \times 0.1$ m $= 0.2$ mol particles

* Boiling point is related to colligative properties of the solution which depends on the no. of particles in solution measured mol particles. ↑ mol particles ↑ boiling point & vice versa

* the no. of particles can be determined via the Van't Hoff factor (i)

13. A 2.05 m aqueous solution of some unknown had a boiling point of 102.1 °C. Which one of the following could be the unknown compound? K_b for H_2O = 0.512 °C/*m*.

[A]

A. NaCl ⟵ circled
B. CH_3OH
C. $C_6H_{12}O_6$
D. Na_2CO_3
E. $CaBr_2$

$\Delta T_b = K_b \times m \times i$

$(102.1 - 100.0)°C = 0.512 \times 2.05 \times i$

$i = 2$ ⟵ has to be an ionic compound that dissociate into two particle

14. When 0.500 g of vitamin K is dissolved in 10.0 g of camphor (K_f = 40.0°C/m), the freezing point of the solution is 4.43°C lower than that of pure camphor. Assuming vitamin K is a nonelectrolyte in camphor, calculate its molar mass.

[C]

A. 0.451 g/mol
B. 55.4 g/mol
C. 451 g/mol ⟵ circled
D. 3.54 x 10⁴ g/mol

① $\Delta T_f = -K_f \times m \times i$

$-4.43°C = -40.0°C \times \frac{mol\ of\ solute}{10.0g\ camphor \times \frac{1kg}{1000g}} \times 1$

mol of solute $= 1.1075 \times 10^{-3}$ mol

② Molar mass of vitamin K

$\frac{0.500\ g}{1.1075 \times 10^{-3}\ mol} = 451.4672686$

≈ 451 g/mol

Because the molar mass of
both compounds are the same
∴ mol fraction = mass fraction

you...
that this is an ideal
solution

15. Two alcohols, isopropyl alcohol, and propyl alcohol, have the same molecular formula, C_3H_8O. A solution of the two is two-thirds by mass isopropyl alcohol has a vapor pressure of 0.110 atm at 313 K. A solution that is one-thirds by mass isopropyl alcohol has a vapor pressure of 0.089 atm at 313 K. What is the vapor pressure of pure isopropyl alcohol ($P°_{iso}$) and the vapor pressure of pure propyl alcohol ($P°_{pro}$) in atm?

A. $P°_{iso}$ | 0.131 | atm

B. $P°_{pro}$ | 0.068 | atm

For an ideal solution the vapor pressure
can be expressed as

① $P_{tot} = (X_{iso} \times P°_{iso}) + (X_{pro} \times P°_{pro})$

Equation 1 $0.110 = (\frac{2}{3} \times P°_{iso}) + (\frac{1}{3} \times P°_{pro})$

Equation 2 $0.089 = (\frac{1}{3} \times P°_{iso}) + (\frac{2}{3} \times P°_{pro})$

② Rearrange Equation 1 in terms of $P°_{pro}$ &
substitute in equation 2

$0.110 = \frac{2}{3} P°_{iso} + \frac{1}{3} P°_{pro}$

$3 \times 0.110 - \frac{2}{3} P_{iso} = \frac{1}{3} P°_{pro}$ $\times 3$

$3(0.110 - \frac{2}{3} P_{iso}) = P°_{pro}$

∴ $P°_{pro} = 0.330 - 2 P_{iso}$

③ $0.089 = \frac{1}{3} P_{iso} + \frac{2}{3} (0.330 - 2 P_{iso})$

$0.089 = \frac{1}{3} P_{iso} + (0.220 - \frac{4}{3} P_{iso})$

$0.089 = 0.220 - P_{iso}$

∴ $P_{iso} = 0.131$ atm

④ $P°_{pro} = 0.330 - 2(0.131) = 0.068$ atm

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Extra Practice Questions: these questions will not be graded

1. The freezing point of acetic acid is typically 16.6 °C. If a sample of 95% w/w acetic acid and 5% w/w water is cooled, at what temperature in degrees Celsius would it freeze? The density of acetic acid is 1.05 g/mL. (K_{fp} = -3.90 °C/m for acetic acid).

solvent ↑ CH_3COOH solute

| 5 | °C |

$\Delta T_f = -k_{fp} \times m \times i$

$T_f(\text{solution}) - T_f(\text{solvent}) = k_{fp} \times m \times i \to 1 \,(CH_3COOH)$

↓?   ↓ 16.6°C   ↓ -3.90°C/m

① Find the molality of acetic acid solution:

$m = \dfrac{\text{mol of solute } (H_2O)}{\text{kg of solvent}} = \dfrac{5g\, H_2O \times \frac{1\,mol\, H_2O}{18.02g\, H_2O}}{9.5g\, CH_3COOH \times \frac{1kg}{1000g}} = 2.920731351\, m$

② $T_f(\text{solution}) - 16.6°C = -3.90°C/m \times 2.920731351\, m \times 1$

∴ $T_f(\text{solution}) = 5.209147731°C$

2. What is the *total* vapor pressure in mm Hg above a solution of 25% v/v methanol dissolved in ethanol? (Methanol: MW = 32.04 g/mol, density = 0.792 g/mL, VP at 25 °C = 97.7 mm Hg; Ethanol: MW = 46.07 g/mol, density = 0.789 g/mL, VP at 25 °C = 58.7 mm Hg).

solute   100-25 = 75% v/v
↳ solvent

| 71 | mm Hg |

∴ $P_{tot} = P_{methanol} + P_{ethanol} = (X_{methanol} \times P°_{methanol}) + (X_{ethanol} \times P°_{ethanol})$

total vapor pressure indicates that both components are volatile

① Determine the mol fraction of methanol & ethanol:

$* 25 mL\, methanol \times \dfrac{0.792g}{mL} \times \dfrac{1\,mol\, methanol}{32.04g\, methanol} = 0.617977528\, mol\, methanol$

$* 75 mL\, ethanol \times \dfrac{0.789g}{mL} \times \dfrac{1\,mol\, ethanol}{46.07g\, ethanol} = 1.284458433\, mol\, ethanol$

$X_{methanol} = \dfrac{0.617977528}{0.617977528\, mol + 1.284458433\, mol\, ethanol} = 0.324834968$

$X_{ethanol} = 1 - 0.324834968 = 0.675165132$

3. Which of the aqueous solutions below will have the **highest** vapor pressure?

| 0 |

A. 0.10 m $MgSO_4$ i = 2 × 0.10 mol = 0.20 mol particles
B. 0.030 m CH_3CH_2OH i = 1 × 0.030 = 0.030 mol particles
C. 0.0090 m $CaCl_2$ i = 3 × 0.0090 = 0.0270 mol particles
D. 0.011 m KCl i = 0.022 mol particles
E. All the solutions have the same vapor pressure

$P_{tot} = (97.7 mmHg \times 0.324834968)$
$+ (58.7 mmHg \times 0.675165132)$
$= 71.36855973\, mmHg$

* Vapor pressure is a physical property related to the conc. of particles measured in moles
* ↑ mol particles of solution ↓ vapor pressure & vice versa
* ∴ the solution with the lowest vapor pressure will have the least mol particles

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Both components are volatile

4. A solution of hexane (volatile solute) and heptane contains a mole fraction of heptane, χ = 0.810 mol and the normal boiling point of the solution is 90.4 °C. The vapor pressure of pure hexane at this temperature is 1425 mm Hg. What is the vapor pressure in mmHg of pure heptane at 90.4 °C?

604 mmHg

$P_{tot} : 760 \text{ torr} = 760 \text{ mmg}$

$$P_{tot} = (P°_{heptane} \times \chi_{heptane}) + (P°_{hexane} \times \chi_{hexane})$$

$$760 = (P°_{heptane} \times 0.810) + (1425 \text{ mmHg} \times (1-0.810))$$

$$\therefore P°_{heptane} = 604.0123457 \text{ mmHg}$$

$$\approx 604 \text{ mmHg}$$

5. Consider the four solutions, and choose which statement is **false** :

E

I) 1 L of pure Water
II) 1 L of water with 0.15 moles of CH_3OH added $i=1$ $\times 0.15 = 0.15$ mol particles
III) 1 L of water with 0.15 moles of CH_3CH_2OH $i=1$ $\times 0.15$ mol $= 0.15$ mol particles
IV) 1 L of water with 0.15 moles of NaCl added $i=2$ $\times 0.30$ mol $= 0.30$ mol particles

A. The pure water solution will have the highest vapor pressure *true*
B. The solution with 0.15 moles of CH_3OH will have the same vapor pressure as the
C. solution with 0.15 moles of CH_3CH_2OH *True*
D. The solution with 0.15 moles of CH_3OH will have higher vapor pressure than the
E. solution with 0.15 moles of NaCl *True*
F. The solution with 0.15 moles of NaCl will have the highest vapor pressure *false*

6. Which of the following effects would **not** result when $CaCl_2$ was added to water?

B

A. The melting point would decrease *True melting/freezing point decrease*
B. The boiling point would decrease *boiling point increase*
C. The vapor pressure would decrease *true*
D. The electrical conductivity of the solution would increase *ionic compound ∴ strong electrolyte*

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7. Choose the **false** statement regarding a 1 L aqueous solution that contains 1.0 g of NaCl. If all statements are true, choose "none of these are false".

[B]

A. $X_{solvent} > X_{solute}$ ~~true (solvent is the greater component)~~
B. T_f(aq. solution) $> T_f(H_2O)$ ~~false~~ T_f (aq. solution) $< T_f (H_2O)$
C. mol % solute $<$ mol % solvent ~~true (see A)~~
D. T_b(aq. solution) $> T_b(H_2O)$ ~~true~~
E. none of these are false

① 45.06 mmHg $\leftarrow P_{tot} = P_{benzene} + P_{toluene} = (P^\circ_{benzene} \times X_{benzene}) + (P^\circ_{toluene} \times X_{toluene})$
95.03 mmHg 28.40 mmHg

8. A mixture of benzene and toluene has a total vapor pressure at 25 °C of 45.06 mmHg. What is the partial pressure of benzene in this solution? The vapor pressure of pure benzene and pure toluene at 25 °C are 95.03 mmHg and 28.40 mmHg respectively.

② $X_{benzene} + X_{toluene} = 1$

[B]

A. 0.7500 mmHg
B. 23.76 mmHg
C. 0.3217 mmHg
D. 21.30 mmHg
E. 16.66 mmHg

$\therefore X_{toluene} = 1 - X_{benzene}$

③ $45.06 = (95.03 \times X_{benzene}) + (28.40 \times (1 - X_{benzene}))$
$45.06 = (95.03 \times X_{benzene}) + 28.40 - (28.40 \times X_{benzene})$
$16.66 = 66.63 \times X_{benzene}$
$\therefore X_{benzene} = 0.2500375206$

④ $P_{benzene} = 95.03$ mmHg $\times 0.2500375206 = 23.76106569 \approx 23.76$ mmHg

9. Arrange the following three aqueous solutions (all 250 cm³ in volume) according to decreasing osmotic pressure at 273 K: 5 g of C_2H_5OH, 5 g $C_6H_{12}O_6$, and 5 g $C_{12}H_{22}O_{11}$.

[A]

A. $C_2H_5OH > C_6H_{12}O_6 > C_{12}H_{22}O_{11}$ 250 ml
B. $C_2H_5OH > C_6H_{12}O_6 = C_{12}H_{22}O_{11}$ mm $C_2H_5OH = 46.08$ g/mol
C. $C_6H_{12}O_6 > C_2H_5OH > C_{12}H_{22}O_{11}$ mm of $C_6H_{12}O_6 = 180.18$ g/mol
D. $C_{12}H_{22}O_{11} > C_6H_{12}O_6 > C2H5OH$ mm of $C_{12}H_{22}O_{11} = 342.34$ g/mol
E. $C_{12}H_{22}O_{11} > C_2H_5OH > C_6H_{12}O_6$ mm all have a mass of 5g

Remember: Colligative properties such as osmotic pressure are related to the concentration of particles measured in mols.

* All of the three compounds are molecular & all have a mass of 5g

$\therefore$ mol $= \dfrac{\text{mass (g)}}{\text{molar mass g/mol}}$

↓
the compound with the lowest molar mass will have the highest conc in mols.

10. Solutions are made that contain 0.10 moles of each of the following compounds in 100 g of H_2O. Choose the compound whose solution will have the highest freezing point.

[B]

A. K_2SO_4 $i = 3 \times 0.10$ mol $= 0.30$ mol particles
B. NaI $i = 2 \times 0.10$ mol $= 0.20$ mol particles
C. $Mg(CH_3CO_2)_2$ $i = 3 \times 0.10 = 0.30$ mol particles
D. $Ca_3(PO_4)_2$ $i = 3 \times 0.10$ mol $= 0.30$ mol particles
E. $Sr(NO_3)_2$

Formula Sheet

Length
1 kilometer = 0.62137 mile
1 inch = 2.54 centimeters (exactly)
1 Ångstrom = 1×10^{-10} meter

Energy
1 joule = 1 kg·m^2/s^2
1 calorie = 4.184 joules
1 Calorie = 1 kilocalorie = 1000 calories
1 L·atm = 101.325 joules

Pressure
1 pascal = 1 N/m^3 = 1 kg/m·s^2
1 atmosphere = 101.325 kilopascals = 760 mm Hg = 760 torr = 14.70 lb/in^2
1 bar = 1×10^5 Pa (exactly)

Temperature
0 K = −273.15°C
K = °C + 273.15
°C = (5/9)(°F − 32)

Mass
1 kg = 2.205 lbs

Volume
1 mL = 1 cm^3 = 1 cc

Constants
c = 2.998×10^8 m/sec
h = 6.626×10^{-34} J·sec^{-1}
R = 0.08206 L·atm/mol·K = 8.314 J/mol·K
Specific heat of water = 4.184 J/g·K
Mass of an electron: 9.109×10^{-31} kg
Mass of a proton: 1.673×10^{-27} kg
RH = 2.18×10^{-18} J
Specific heat of water = 4.184 J/g·K
STP = 273.15 K and 1 atm
Avogadro's number: 6.022×10^{23}

Equations
d (density) = m/V
$P_1V_1 = P_2V_2$
$V_1/T_1 = V_2/T_2$
$P_1V_1/n_1T_1 = P_2V_2/n_2T_2$
PV = nRT
$(P + a(n^2/V^2))·(V - nb) = nRT$
molar mass (M) = mRT/PV
density (d) = MP/RT
$x_A = n_A/n_{tot} = P_A/P_{tot} = V_A/V_{tot}$
$P_{tot} = P_A + P_B + ...$
$n_{tot} = n_A + n_B + ...$

$$\mu_{rms} = \sqrt{\frac{3RT}{M}}$$

$$\frac{Rate\ of\ effusion\ A}{Rate\ of\ effusion\ B} = \sqrt{\frac{MW_B}{MW_A}}$$

Q = C × ΔT = $c_{specific}$ × m × ΔT
Q = n × ΔH (kJ/mol) = m × ΔH (kJ/g)
w = −PΔV
ΔE = q + w
ΔH° = ΣnΔHf°(products) − ΣnΔHf°(reactants)
ΔH° = ΣnΔH°(bonds broken) − ΣnΔH°(bonds formed)
E=hν
c=λν
λ = h/mv

$$\Delta E = -2.18 \times 10^{-18} J (\frac{1}{n_f^2} - \frac{1}{n_i^2})$$

$$\ln\left(\frac{P_2}{P_1}\right) = \frac{\Delta H_{vap}}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$$

$C_g = kP_g$
$P_{solution} = P_{solvent} X_{solvent}$
$P_{solution} = \sum P_j = \sum P_j X_j$
$\Delta T_b = K_b m i$
$\Delta T_f = K_f m i$
π = MRTi

Thermodynamic and Electrochemistry
S = k_b × ln(W)
k_b = 1.381 × 10^{-23} J/K
ΔS = q_{rev}/T
ΔS_{surr} = q_{surr}/T = −q_{rev}/T
ΔS_{univ} = ΔS_{sys} + ΔS_{surr}
$\Delta S°_{rxn}$ = Σν$S°_{products}$ − Σν$S°_{reactants}$
$\Delta H°_{rxn}$ = Σν$H°_{products}$ − Σν$H°_{reactants}$
$\Delta G°_{rxn}$ = Σν$G°_{products}$ − Σν$G°_{reactants}$
ΔG = ΔH − TΔS
ΔG = ΔG° + RT·lnQ
R=8.314 J/mol.K
ΔG° = −RT·lnK
ΔG= −nFE_{cell}
F = 96485 J/(V·mol e$^-$)
E°$_{cell}$ = RT/nF lnK
E°$_{cell}$ = (0.0257/n) lnK = (0.0592/n) logK
E_{cell} = E°$_{cell}$ − (RT/nF) lnQ
E_{cell} =E°$_{cell}$ − (0.0257/n) lnQ
Electrolysis: Q (total charge) = I × t = n × F

Integrated Rate Laws & half-life

$$\ln \frac{[A]}{[A]_0} = -kt$$

$$\frac{1}{[A]} = kt + \frac{1}{[A]_0}$$

$$[A] = -kt + [A]_0$$

$$t_{1/2} = \frac{[A]_0}{2k}$$

$$t_{1/2} = \frac{\ln 2}{k} = \frac{0.693}{k}$$

$$t_{1/2} = \frac{1}{k[A]_0}$$

$$\ln \frac{k_2}{k_1} = -\frac{E_a}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$$

Equilibrium and Acid / Base

$K_P = K_c \times (RT)^{\Delta n}$

$pH = -\log[H_3O^+]$

$K_w = 1.0 \times 10^{-14}$ at 25 °C

$K_w = [H_3O^+] \times [OH^-]$

$K_w = K_a \times K_b$

$pK_a = -\log[K_a]$

Buffer: $pH = pK_a + \log \frac{[A^-]}{[HA]}$

$$\ln \frac{K_2}{K_1} = \frac{\Delta H^{\circ}_{rxn}}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$$

Periodic Table of the Elements

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 H 1.01																	2 He 4.00
3 Li 6.94	4 Be 9.01											5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
11 Na 22.99	12 Mg 24.31											13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.06	17 Cl 35.45	18 Ar 39.95
19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.87	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.38	31 Ga 69.72	32 Ge 72.63	33 As 74.92	34 Se 78.97	35 Br 79.90	36 Kr 83.80
37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.95	43 Tc [97]	44 Ru 101.07	45 Rh 102.91	46 Pd 106.42	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.71	51 Sb 121.76	52 Te 127.60	53 I 126.90	54 Xe 131.29
55 Cs 132.91	56 Ba 137.33	57 La 138.91	72 Hf 178.49	73 Ta 180.95	74 W 183.84	75 Re 186.21	76 Os 190.23	77 Ir 192.22	78 Pt 195.08	79 Au 196.97	80 Hg 200.59	81 Tl 204.38	82 Pb 207.2	83 Bi 208.98	84 Po [209]	85 At [210]	86 Rn [222]
87 Fr [223]	88 Ra [226]	89 Ac [227]	104 Rf [267]	105 Db [268]	106 Sg [269]	107 Bh [270]	108 Hs [269]	109 Mt [277]	110 Ds [281]	111 Rg [282]	112 Cn [285]	113 Nh [286]	114 Fl [290]	115 Mc [290]	116 Lv [293]	117 Ts [294]	118 Og [294]

57 La 138.91	58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm [145]	62 Sm 150.36	63 Eu 151.96	64 Gd 157.25	65 Tb 158.93	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.05	71 Lu 174.97
89 Ac [227]	90 Th 232.04	91 Pa 231.04	92 U 238.03	93 Np [237]	94 Pu [244]	95 Am [243]	96 Cm [247]	97 Bk [247]	98 Cf [251]	99 Es [252]	100 Fm [257]	101 Md [258]	102 No [259]	103 Lr [262]