Recitation Worksheet 5: Properties of Solutions (11.1 – 11.3)

Name: Key

MyID:

Instructions:

1. Please enter your first and last name as it appears on the eLC classlist (do not use a nickname).
2. Your UGA myID is a combination of letters and numbers (example: Dr. Abdelrahman MyID is ema88805). **Do not use your 81x number.**

a. If you do not have access to a printer, type your answers in the worksheet PDF and then upload it to **Gradescope** by Thursday, September 29th at 11:59 pm. Write your work on separate sheets of paper, convert to a PDF and upload to the "Recitation Worksheet 5 Dropbox" on eLC.

b. If you have access to a printer, print out the worksheet, write your answer in the answer boxes, and show your work on it when appropriate. Then convert it to a PDF and upload to **Gradescope** by Thursday, September 29th at 11:59 pm. You do not need to upload anything to eLC.

c. There is a **Gradescope App** available for both iOS and Android devices that allows you to scan and submit your printed work or you can submit your fillable PDF directly. Detailed instructions on how to access and use the app can be found on your CHEM 1212 class eLC page under content ⟶ Welcome module ⟶ Gradescope ⟶ Gradescope new mobile app.

3. Answers must be written in the corresponding answer box, or no credit will be awarded.
4. The pages must be in the correct order and have the same layout as the original, or Gradescope will not be able to read it.
5. The instructions for uploading worksheets to Gradescope can be found in the Content area of eLC in the Welcome Module.

H-bonded to a highly electronegative atom ← H–Ö–H → water is capable of forming H-bond (polar)

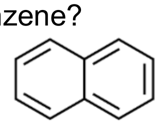
Benzene has C–H bonds which are non-polar ∴ it is capable of forming LDFs

1. Substances that dissolve in water (H_2O) generally do not dissolve in benzene (C_6H_6). However, some substances are moderately soluble in both. Which of the substances below do you think would be **moderately** soluble in **both** water and benzene?

Answer: D

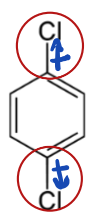
For this question you are going to use the idea of "likes dissolves likes"

A. Naphthalene



Naphthalene has a similar structure to benzene (non-polar) ∴ capable of forming LDFs. Naphthalene is soluble in benzene but not in H_2O (polar)

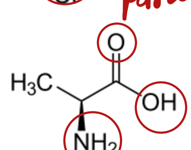
B. *para*-dichlorobenzene



Although C–Cl bonds are polar there are two Cl on the benzene ring with opposing dipoles

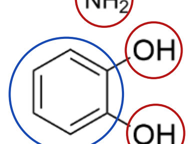
para-dichlorobenzene is a non-polar molecule ∴ capable of forming LDFs. para-dichlorobenzene is soluble in benzene but not in water

C. Alanine (an amino acid)



C=O bond is polar can form DD forces while NH_2 & OH are capable of forming H-bond ∴ the alanine is an overall polar molecule (soluble in water but not in benzene)

D. *ortho*-hydroxyphenol



capable of forming H-bond

the cyclic ring consists of C–H bond ∴ non-polar (LDFs) similar to benzene

ortho-hydroxyphenol is moderately soluble in both benzene & water

2. You want to prepare a perfectly roasted turkey for a family gathering and you must soak the turkey for at least 8 hours in a 3.87% by mass brine solution (a solution consisting of salt (NaCl) dissolved in water). How many liters of water are needed to dissolve 725 g of NaCl to prepare the 3.87% by mass brine solution?

18.0	L

3.87% by mass brine solution =

$\frac{3.87\text{ g NaCl}}{100\text{ g solution}}$ → solute + solvent

Mass of water in 3.87% by mass brine solution =
100.00 g solution − 3.87 g (NaCl)
= 96.13 g H_2O

Liters of water needed to dissolve 725 g of NaCl

$725\text{ g NaCl} \times \frac{96.13\text{ g }H_2O}{3.87\text{ g NaCl}} \times \frac{1.00\text{ mL}}{\text{g }H_2O} \times \frac{1\text{ L}}{1000\text{ mL}}$

= 18.00885 ~ 18.0 L

3. In CHEM 1212 lab, you are working on a freezing point depression experiment, and you decide to perform a rather dangerous trial. Instead of water as a solvent and $CaCl_2$ as a solute, you decide to use carbon disulfide (neurotoxic agent) as a solvent and iodine as a solute. In the first step you want to prepare a 0.286 m solution of iodine in carbon disulfide. How many grams of iodine (I_2) must be dissolved in 625 mL of carbon disulfide solvent (CS_2, density = 1.261 g/mL) to produce the 0.286 m solution?

57.2	g

0.286 m solution of iodine in CS_2 =

$\frac{0.286\text{ mol }I_2}{1\text{ kg }CS_2}$

Molality = $\frac{\text{mol of solute}}{1\text{ kg of solvent}}$

Mass of I_2 to be dissolved in 625 mL of CS_2 =

$625\text{ mL }CS_2 \times \frac{1.261\text{ g }CS_2}{\text{mL}} \times \frac{1\text{ kg}}{1000\text{ g}} \times \frac{0.286\text{ mol }I_2}{1\text{ kg }CS_2} \times \frac{253.80\text{ g }I_2}{1\text{ mol }I_2}$

↓ solvent

= 57.20747 ~ 57.2 g I_2

4. Henry's law constant for gas X is 3.30 x 10^{-2} M/atm. What total volume of solution is needed to completely dissolve 1.65 L of gas at a pressure of 725 torr and a temperature of 25 °C? (1 atm = 760 torr)

Answer: 2.04 L

Henry's law $C_{gas} = K_H P_{gas}$

$K_H = 3.30 \times 10^{-2} \frac{mol}{L \cdot atm}$

$P_{gas} = 725\ torr \times \frac{1\ atm}{760\ torr} = 0.95394737\ atm$

$C_{gas} = \frac{mol\ of\ gas}{Liters\ of\ solution}$ → can be determined using ideal gas constant $PV = nRT$; Liters of solution → to be determined

Using the ideal gas law to determine the mol of gas

$0.95394737\ atm \times 1.65\ L = n \times 0.08206 \frac{L \cdot atm}{mol \cdot K} \times (25 + 273.15)$

$\therefore n = 0.06433219\ mol$

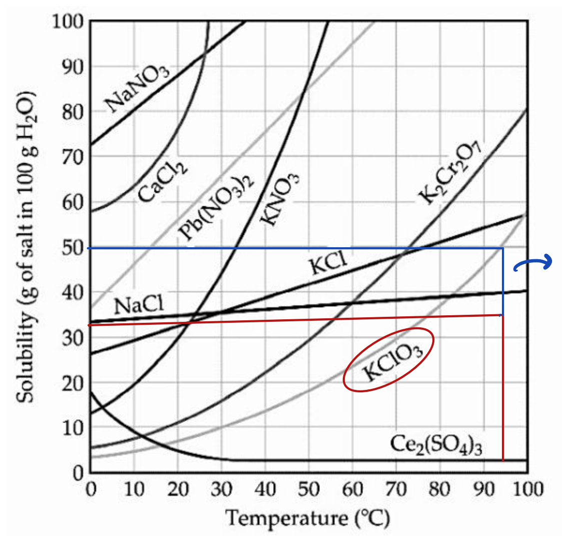
Using Henry's law constant $C_{gas} = K_H P_{gas}$

$C_{gas} = \frac{mol\ of\ gas}{L\ of\ soln} = K_H \times P_{gas} \Rightarrow \therefore L\ of\ soln = \frac{mol\ of\ gas}{K_H \times P_{gas}}$

$= \frac{0.06433219\ mol}{3.30 \times 10^{-2} \frac{M}{atm} \times 0.95394737\ atm}$

$= 2.04\ L$

5. Refer to the plot below solubility versus temperature to answer the following question.



→ at 95 °C the solution becomes saturated when there is 50 g of $KClO_3$ in 100 g water

A solution that is 2.75 m of potassium chlorate (molar mass = 122.55 g/mol) at 95 °C is considered

Answer: B

A. Hydrated
B. Unsaturated
C. Saturated
D. Supersaturated
E. Dehydrated

2.75 m $KClO_3$

$\frac{2.75\ mol\ KClO_3}{1\ kg\ H_2O}$ ⇒ convert to grams of salt in 100 g of water

$\frac{2.75\ mol\ KClO_3}{1\ kg\ H_2O} \times \frac{122.55\ g\ KClO_3}{1\ mol\ KClO_3} \times \frac{1\ kg}{1000\ g} \times 100\ g\ H_2O$

$= 33.7\ g\ KClO_3$ in $100\ g\ H_2O$

Molar mass of H_3PO_4 = 97.99 g/mol

6. Phosphoric acid is commonly used as a cleaning detergent for removal of rust and stains. If a commercial detergent contains 26.0% by mass H_3PO_4 and has a density of 1.148 g/cm^3 at 30 °C. What is the

1 g/cm^3 = 1 g/mL

A. Molality of H_3PO_4 in the detergent solution?

3.59	*m*

$$\text{Molality} = \frac{\text{mol of } H_3PO_4}{1 \text{ kg of solvent } (H_2O)}$$

$$26.0\% \text{ by mass } H_3PO_4 = \frac{26.0 \text{ g } H_3PO_4}{100 \text{ g of solution}}$$

$\therefore$ mass of H_2O = 100 g solution − 26.0 g H_3PO_4 = 74.0 g H_2O

$$\frac{26.0 \text{ g } H_3PO_4}{74.0 \text{ g } H_2O} \times \frac{1 \text{ mol } H_3PO_4}{97.99 \text{ g } H_3PO_4} \times \frac{1000 \text{ g}}{1 \text{ kg}}$$

= 3.59 m

B. Molarity of H_3PO_4 in the solution?

3.05	M

$$\text{Molarity} = \frac{\text{mol of solute}}{\text{Liters of solution}}$$

$$\frac{26.0 \text{ g } H_3PO_4}{100 \text{ g solution}} \times \frac{1 \text{ mol } H_3PO_4}{97.99 \text{ g } H_3PO_4} \times \frac{1.148 \text{ g solution}}{\text{mL}} \times \frac{1000 \text{ mL}}{1 \text{ L}}$$

= 3.05 M

C. Mole fraction of H_3PO_4 in the detergent solution?

0.0607

$$\text{Mole fraction of } H_3PO_4 = \frac{\text{mol } H_3PO_4}{\text{mol } H_3PO_4 + \text{mol } H_2O}$$

From part A you have the mass of H_2O = 74.0 g

$$\text{mol of } H_2O = 74.0 \text{ g } H_2O \times \frac{1 \text{ mol } H_2O}{18.01 \text{ g } H_2O} = 4.1088284 \text{ mol } H_2O$$

$$\text{mol of } H_3PO_4 = 26.0 \text{ g} \times \frac{1 \text{ mol } H_3PO_4}{97.99 \text{ } H_3PO_4} = 0.2653332 \text{ mol } H_3PO_4$$

$$\text{Mole fraction of } H_3PO_4 = \frac{0.2653332 \text{ mol } H_3PO_4}{0.2653332 \text{ mol } H_3PO_4 + 4.1088284 \text{ mol } H_2O}$$

= 0.0607

7. Which cation is expected to have the largest hydration energy?

E

A. Li^{+}
B. Ca^{2+}
C. Ba^{2+}
D. Cs^{+}
E. Al^{3+}

this is related to lattice energy. the higher the charge the larger the hydration energy

8. A water sample is found to have 9.4 ppb of chloroform, $CHCl_3$. How many grams of $CHCl_3$ would be found in a glass of this water? (One glass of water = 250 mL).

2.4×10^{-6}	g

ppb = μg of solute / kg of solution

For very dilute solutions the density ~1.0 g/mL

$\frac{9.4\ \mu g\ CHCl_3}{1\ kg\ of\ solution} \times \frac{1\ mg\ CHCl_3}{1000\ \mu g\ CHCl_3} \times \frac{1\ g\ CHCl_3}{1000\ mg\ CHCl_3} \times \frac{1\ kg\ soln}{1000\ g\ soln} \times \frac{1.0\ g}{mL} \times 250\ mL$

$= 2.4 \times 10^{-6}$ g

Molar mass of KOH = 56.11 g/mol

9. You are performing an experiment which requires you to prepare a 0.250 m KOH solution, but you only have a 100.0 mL of a stock (concentrated) solution containing 109.2 g/L KOH (density = 1.012 g/cm³). What is the mass of water needs to be added to the 100 mL stock solution to obtain 0.250 m KOH solution?

688	g

① Determine the # of moles of KOH in stock solution

$\frac{109.2\ g\ KOH}{1\ L\ solution} \times \frac{1\ mol\ KOH}{56.11\ g\ KOH} \times \frac{1\ L}{1000\ mL} \times 100\ mL = 0.1946\ mol\ KOH$ in stock solution

② Using the mol of KOH in the stock solution you can determine the mass of water in the final solution (0.250 m)

$0.1946\ mol\ KOH \times \frac{1\ kg\ H_2O}{0.250\ mol\ KOH} = 0.77847\ kg = 778\ g$ → mass of water in final solution

③ Determine the mass of H_2O in the stock solution

Mass of solution = $100.0\ mL \times \frac{1.012\ g}{mL} = 101.2\ g$ solution

Mass of KOH in solution = $\frac{109.2\ g\ KOH}{1\ L\ solution} \times \frac{1\ L}{1000\ mL} \times 100.0\ mL$ solution $= 10.92\ g$

Mass of H_2O in stock solution = $101.2\ g - 10.92\ g = 90.28\ g$

④ Mass of H_2O added = $778\ g - 90.28\ g = 687.72 \approx 688\ g$

Ionic solid

10. Lithium iodide (LiI) is used as a solid-state electrolyte for **high-temperature batteries**. When LiI is dissolved in water, the solution becomes hotter. Which of the following statement(s) is true?

E

A. The dissolution of LiI is exothermic ✓ (solution is hot ∴ dissolution of LiI is exothermic)

B. $|\Delta H_{solute}| < |\Delta H_{hydration}|$ $\Delta H_{soln} = \Delta H_{solute}(+) - \Delta H_{hydration}(-)$ ✓

C. ΔH_{soln} is negative and ΔS_{soln} is positive ✓

D. The solute-solvent interaction is greater than the solute-solute and the solvent-solvent interaction ✓

(E.) All the above statements are true

11. The concentration nitrogen gas in the ocean at 25 °C is 445 μM and Henry's law constant for nitrogen is 0.61 x 10^{-3} mol/L·atm.

A. What is the mass of nitrogen in a liter of ocean's water? $1\ M = 10^6\ \mu M$

0.0125

g

$$\frac{445 \times 10^{-6}\ mol\ N_2}{1\ L\ of\ sea\ water} \times \frac{28.0\ g\ N_2}{1\ mol} = 0.0125\ g/L \text{ or } 0.0125\ g$$

$$445\ \mu M \times \frac{1\ M}{10^6\ \mu M}$$

B. Calculate the partial pressure of N_2 in the atmosphere.

0.73

atm

Using Henry's law

$C_{gas} = K_H P_{gas}$

$$445 \times 10^{-6}\ \frac{mol}{L} = 0.61 \times 10^{-3}\ atm \times P_{atm}$$

$\therefore P = 0.73$

$1\ L = 10\ dL$

12. A person is considered legally intoxicated with a blood alcohol level of 80. mg/dL. If blood plasma has a density of 1.025 g/mL, what is this concentration expressed in **ppm**?

780

ppm

$$ppm = \frac{mg\ of\ solute}{kg\ of\ solution}$$

$$\frac{80.\ mg}{dL} \times \frac{10\ dL}{1\ L} \times \frac{1\ L}{1000\ mL} \times \frac{1\ mL}{1.025\ g} \times \frac{1000\ g}{1\ kg}$$

$= 780\ ppm$

13. Calculate the mole fraction of the solute in each of the following solutions:

A. 0.112 M $C_6H_{12}O_6$ (density = 1.006 g/mL)

0.00204

$$\frac{0.112 \text{ mol } C_6H_{12}O_6}{1 \text{ L solution}}$$

Mass of solution = $1 \text{ L solution} \times \frac{1000 \text{ mL}}{1 \text{ L}} \times \frac{1.006 \text{ g}}{\text{mL}}$

$= 1006 \text{ g solution}$

Mass of $C_6H_{12}O_6$ = $0.112 \text{ mol } C_6H_{12}O_6 \times \frac{180.1 \text{ g } C_6H_{12}O_6}{1 \text{ mol } C_6H_{12}O_6} =$

Mass of water = $1006 \text{ g} - 20.17 \text{ g} = 986 \text{ g}$

$986 \text{ g } H_2O \times \frac{1 \text{ mol } H_2O}{18.01 \text{ g } H_2O} = 54.7 \text{ mol}$

$$\frac{0.112}{0.112 + 54.7} = 0.00204$$

B. 3.20% C_2H_5OH by volume (density of pure C_2H_5OH= 0.789 g/mL)

0.0101

3.20% by volume C_2H_5OH to mole fraction of C_2H_5OH in solution

$$\frac{3.20 \text{ mL } C_2H_5OH}{100 \text{ mL solution}}$$

volume of $H_2O = 100 - 3.20 =$

$96.8 \text{ mL} \times \frac{1.00 \text{ g } H_2O}{\text{mL } H_2O} \times \frac{1 \text{ mol } H_2O}{18.01 \text{ g } H_2O}$

$= 5.37 \text{ mol}$

Moles of $C_2H_5OH = 3.20 \text{ mL} \times \frac{0.789 \text{ g}}{\text{mL}} \times \frac{1 \text{ mol } C_2H_5OH}{46.07 \text{ g } C_2H_5OH}$

$= 0.0548$

$$\chi_{C_2H_5OH} = \frac{0.0548}{5.37 + 0.0548} = \frac{0.0548}{5.42}$$

$= 0.0101$