Practice Problems on **Recrystallization**

KEY

1. The solubility of *p*-nitroaniline in water is as follows:

2.22 g/100 mL hot water
0.08 g/100 mL cold water

If you wanted to recrystallize 1.75 g of *p*-nitroaniline,

(a) what is the minimum amount of water needed?

$$(1.75\text{ g solid})\left(\frac{100\text{ mL water}}{2.22\text{ g solid}}\right) = \boxed{78.8\text{ mL}}\text{ of water}$$

(b) how many grams of *p*-nitroaniline, out of the original 1.75 g, could be recovered from 80.0 mL of water?

$$(80.0\text{ mL }H_2O)\left(\frac{0.08\text{ g solid}}{100\text{ mL }H_2O}\right) = 0.064\text{ g left in solution}$$

$$1.75 - 0.064 = \boxed{1.69\text{ g}}\text{ recovered}$$

2. The solubility of quercetin in alcohol is as follows:

5.5 g/100 mL hot alcohol
0.40 g/100 mL cold alcohol

If you wanted to recrystallize 2.67 g of quercetin

(a) what is the minimum amount of alcohol needed?

$$(2.67\text{ g solid})\left(\frac{100\text{ mL alcohol}}{5.5\text{ g solid}}\right) = 4\bar{8}.545\text{ mL} = \boxed{49\text{ mL}}\text{ of alcohol}$$

(b) how many grams of quercetin, out of the original 2.67 g, could be recovered from 50.0 mL of alcohol?

$$(50.0\text{ mL alcohol})\left(\frac{0.40\text{ g solid}}{100\text{ mL alcohol}}\right) = 0.20\text{ g left in solution}$$

$$2.67 - 0.20 = \boxed{2.47\text{ g}}\text{ recovered}$$

CHEM 3312
SOLUTION CONCENTRATION
Answers to exercises

1. How many milliliters of 12.0 M aqueous HCl solution (concentrated hydrochloric acid) would be required to prepare 150 mL of 0.600 M HCl solution?

$$(150\text{ mL dilute sol'n})\left(\frac{0.600\text{ mmole HCl}}{1\text{ mL dilute sol'n}}\right) = 90.0\text{ mmole HCl}$$

$$(90.0\text{ mmole HCl})\left(\frac{1\text{ mL conc. sol'n}}{12.0\text{ mmole HCl}}\right) = 7.50\text{ mL conc. sol'n}$$

2. If 10.0 mL of 0.520 M glucose solution is diluted to 40.0 mL, what is the final concentration of glucose?

$$(10.0\text{ mL conc. sol'n})\left(\frac{0.520\text{ mmole glucose}}{1\text{ mL conc. sol'n}}\right) = 5.20\text{ mmole glucose}$$

$$\frac{5.20\text{ mmole glucose}}{40.0\text{ mL dil. sol'n}} = 0.130\text{ mmole glucose / mL dil. sol'n}$$

$$= 0.130\text{ M}$$

3. How would you prepare 250 mL of a 1.64 M solution of Na_2CO_3 (106.0 g/mole)?

$$(250\text{ mL sol'n})\left(\frac{1\text{ L sol'n}}{1000\text{ mL sol'n}}\right)\left(\frac{1.64\text{ moles }Na_2CO_3}{1\text{ L sol'n}}\right)\left(\frac{106.0\text{ g }Na_2CO_3}{1\text{ mole }Na_2CO_3}\right) = 43.\overline{4}6\text{ g }Na_2CO_3$$

Dissolve 43.5 g of Na_2CO_3 in enough water to make 250 mL of solution.

4. Calculate both the molarity and the molality for an 8.000 % *w/w* aqueous solution of NaCl (58.44 g/mole) for which the density is 1.056 g/mL.

$$\left(\frac{8.000\text{ g NaCl}}{100\text{ g sol'n}}\right)\left(\frac{1.056\text{ g sol'n}}{1\text{ mL sol'n}}\right)\left(\frac{1000\text{ mL sol'n}}{1\text{ L sol'n}}\right)\left(\frac{1\text{ mole NaCl}}{58.44\text{ g NaCl}}\right)$$

$$= 1.44\overline{5}6\text{ mole NaCl / L sol'n} = 1.446\text{ M}$$

$$\left(\frac{8.000\text{ g NaCl}}{92.000\text{ g solvent}}\right)\left(\frac{1000\text{ g solvent}}{1\text{ kg solvent}}\right)\left(\frac{1\text{ mole NaCl}}{58.44\text{ g NaCl}}\right) = 1.48\overline{7}96\text{ mole NaCl / kg solvent}$$

$$= 1.488\text{ m}$$

$$\begin{array}{r} 100.0000000... \\ -\quad 8.000 \\ \hline 92.000 \end{array}$$

Practice Problems on EXTRACTION

1. For compound **Y**, the distribution coefficient (methylene chloride/water) is 8.00. Calculate the amount of **Y** that could be extracted from a solution containing 3.00 g of **Y** in 100 mL of water by

   (a) a single extraction with 100 mL of methylene chloride.

   x = amount of Y extracted.

$$\frac{x/100}{(3-x)/100} = 8 \qquad \frac{x}{3-x} = 8$$

$$x = (8)(3-x) \qquad x = 24 - 8x \qquad 9x = 24 \qquad x = \mathbf{2.67}\ \text{g}$$

   (b) two successive extractions, each with 50 mL of methylene chloride.

$$\frac{x_1/50}{(3-x_1)/100} = 8 \qquad \frac{2x_1}{3-x_1} = 8$$

$$2x_1 = (8)(3-x_1) \qquad 2x_1 = 24 - 8x_1$$

$$10x_1 = 24 \qquad x_1 = \mathit{2.40}\ \text{g}$$

$$3.00 - 2.40 = 0.60\ \text{g}$$

$$\frac{x_2/50}{(0.6-x_2)/100} = 8 \qquad \frac{2x_2}{0.6-x_2} = 8$$

$$2x_2 = (8)(0.6-x_2) \qquad 2x_2 = 4.8 - 8x_2$$

$$10x_2 = 4.8 \qquad x_2 = \mathit{0.480}\ \text{g}$$

$$\text{Total} = \mathit{2.40} + \mathit{0.480} = \mathbf{2.88\ g}$$

2. For compound **X**, the distribution coefficient (methylene chloride/water) is 1.00. Calculate the amount of **X** that could be extracted from a solution containing 1.00 g of **X** in 100 mL of water by

   (a) a single extraction with 100 mL of methylene chloride.

   x = amount of X extracted.

$$\frac{x/100}{(1-x)/100} = 1 \qquad \frac{x}{1-x} = 1$$

$$x = (1)(1-x) \qquad x = 1 - x \qquad 2x = 1 \qquad x = \mathbf{0.500}\ \text{g}$$

   (b) two successive extractions, each with 50 mL of methylene chloride.

$$\frac{x_1/50}{(1-x_1)/100} = 1 \qquad \frac{2x_1}{1-x_1} = 1$$

$$2x_1 = (1)(1 - x1) \qquad 2x_1 = 1 - x_1$$

$$3x_1 = 1 \qquad x_1 = \mathit{0.333}\ \text{g}\ (1/3)$$

$$1.00 - 0.333 = 0.67\ \text{g}\ (2/3)$$

$$\frac{x_2/50}{(2/3-x_2)/100} = 1 \qquad \frac{2x_2}{2/3-x_2} = 1$$

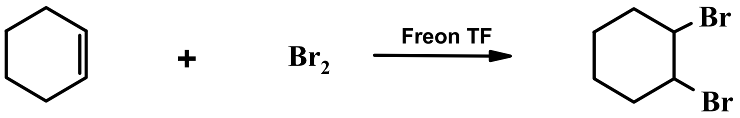
$$2x_2 = (1)(2/3 - x_2) \qquad 2x_2 = 2/3 - x_2$$

$$3x_2 = 2/3 \qquad x_2 = 2/9 = \mathit{0.222}\ \text{g}$$

$$\text{Total} = 1/3 + 2/9 = 3/9 + 2/9 = 5/9 = \mathbf{0.556}\ \text{g}$$

SPECIAL PROBLEMS *** STOICHIOMETRY

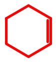
1.



	Cyclohexene	Bromine	1,2-Dibromocyclohexane
molecular weight	**82.15 g/mole**		**241.96 g/mole**
density	**0.811 g/mL**		

A student mixes 2.54 mL of cyclohexene with 30 mL of 1.0 M bromine solution in Freon TF.

(a) What is the limiting reagent?



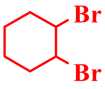
✓ **cyclohexene**

$$2.54\ \text{mL} \xrightarrow{\text{X } 0.811\ \text{g/mL}} 2.0\bar{5}994\ \text{g} \xrightarrow{\div 82.15\ \text{g/mole}} 0.025\bar{0}75\ \text{mole}$$ ✓

Br_2 bromine

$$30.0\ \text{mL} \xrightarrow{1.0\ \text{mmole/mL}} 30\ \text{mmoles} \xrightarrow{\div 1000\ \text{mmole/mole}} 0.030\ \text{mole}\ \text{(excess)}$$

(b) If the student obtains 3.75 g of 1,2-dibromocyclohexane, what is the per cent yield?



$$0.025\bar{0}75\ \text{mole} \xrightarrow{\text{X } 241.96\ \text{g/mole}} 6.0\bar{6}72\ \text{g}\ \ \text{theoretical yield}$$

$$\frac{3.75\ \text{g}}{6.0\bar{6}72\ \text{g}} \text{ X } 100 = \mathbf{61.8\%}$$

2.

$CH_3{-}CH_2{-}CH_2{-}I$ + **NaCN** → **$CH_3{-}CH_2{-}CH_2{-}C{\equiv}N$** + **NaI**

Propyl iodide
Density:
1.743 g/mL
Formula Weight:
169.99 g/mole

Butyronitrile
Formula Weight:
69.11 g/mole

A student mixes 19.5 mL of pure propyl iodide with 180 mL of 1.00 M NaCN solution.

(a) What is the limiting reagent?

$CH_3{-}CH_2{-}CH_2{-}I$ Propyl iodide

$$19.5\ \text{mL} \xrightarrow{\text{X } 1.743\ \text{g/mL}} 33.\bar{9}885\ \text{g} \xrightarrow{\div 169.99\ \text{g/mole}} 0.199\bar{9}\ \text{mole}\quad \text{(excess)}$$

NaCN ✓ **sodium cyanide**

$$180\ \text{mL} \xrightarrow{\text{X } 1.0\ \text{mmole/mL}} 180\ \text{mmoles} \xrightarrow{\div 1000\ \text{mmole/mole}} 0.180\ \text{mole}$$ ✓

(b) If 9.33 g of butyronitrile is obtained, what is the per cent yield?

Butyronitrile:

$$0.180\ \text{mole} \xrightarrow{\text{X } 69.11\ \text{g/mole}} 12.\bar{4}398\ \text{g}\ \ \text{theoretical yield}$$

$$\frac{9.33\ \text{g}}{12.\bar{4}398\ \text{g}} \text{ X } 100 = \mathbf{75.0\%}$$

Special Problems: Distillation and Vapor Pressure

1. At a temperature of 40EC, the vapor pressures of carbon disulfide (CS_2) and carbon tetrachloride are as follows:

   CS_2 .... 618 mm Hg

   CCl_4........... 215 mm Hg

   For a liquid mixture of CS_2 and CCl_4 in which the mole fraction of CS_2 is 0.250, calculate:

   (a) The total vapor pressure of the mixture at 40EC.

$$\begin{aligned} CS_2\text{:}\quad & (618\text{ mm Hg})((0.250) = 15\bar{4}.5\text{ mm Hg} \\ CCl_4\text{:}\quad & (215\text{ mm Hg})((0.750) = 16\bar{1}.25\text{ mm Hg} \\ \hline & \text{Total} = 31\bar{5}.75 \Rightarrow 316\text{ mm Hg} \end{aligned}$$

   (b) The mole fraction of CS_2 in the vapor just above the liquid at 40EC.

$$\frac{15\bar{4}.5\text{ mm Hg}}{31\bar{5}.75\text{ mm Hg}} = 0.489$$

2. At a temperature of 65EC, the vapor pressures of hexane and heptane are as follows:

   Hexane ...... 675 mm Hg

   Heptane ..... 253 mm Hg

   For a liquid mixture of hexane and heptane in which the mole fraction of hexane is 0.350, calculate:

   (a) The total vapor pressure of the mixture at 65EC.

$$\begin{aligned} \text{HEXANE:}\quad & (675\text{ mm Hg})((0.350) = 23\bar{6}.25\text{ mm Hg} \\ \text{HEPTANE:}\quad & (253\text{ mm Hg})((0.650) = 16\bar{4}.45\text{ mm Hg} \\ \hline & \text{Total} = 40\bar{0}.7 \Rightarrow 401\text{ mm Hg} \end{aligned}$$

   (b) The mole fraction of hexane in the vapor just above the liquid at 65EC.

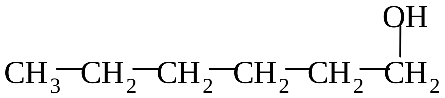
$$\frac{23\bar{6}.25\text{ mm Hg}}{40\bar{0}.7\text{ mm Hg}} = 0.590$$

PROBLEMS IN QUALITATIVE CHEMICAL ANALYSIS OF ORGANIC COMPOUNDS

Describe how you could distinguish between the two compounds in each pair using a *simple* **chemical** test. Encircle whichever compound would respond positively to the test. Give the *name* of the test (e. g., *CrO_3*) or describe BRIEFLY how it is *done* (e.g., *add unknown to chromic acid solution in acetone*). Describe the results observed in a positive test (e.g., *orange solution changes to blue-green precipitate*). If you know more than one test that could be used to make the required distinction, describe only **one** of them. Assume all compounds are water-**in**soluble.

KEY

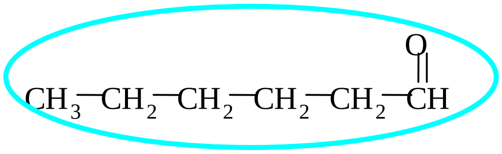
(a)



$CH_3-CH_2-CH_2-CH_2-CH_2-\overset{\overset{\displaystyle OH}{|}}{CH_2}$

hexyl alcohol

or

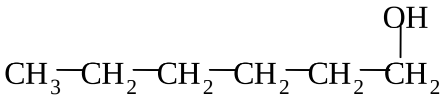


$CH_3-CH_2-CH_2-CH_2-CH_2-\overset{\overset{\displaystyle O}{\|}}{CH}$

caproaldehyde

DNP: *orange precipitate forms*

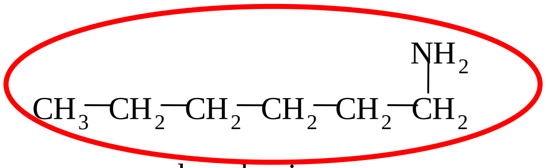
(b)



$CH_3-CH_2-CH_2-CH_2-CH_2-\overset{\overset{\displaystyle OH}{|}}{CH_2}$

hexyl alcohol

or

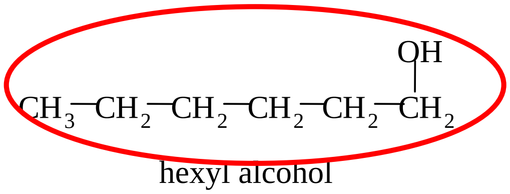


$CH_3-CH_2-CH_2-CH_2-CH_2-\overset{\overset{\displaystyle NH_2}{|}}{CH_2}$

hexylamine

5% HCl: *compound dissolves*

(c)



$CH_3-CH_2-CH_2-CH_2-CH_2-\overset{\overset{\displaystyle OH}{|}}{CH_2}$

hexyl alcohol

or $CH_3-CH_2-CH_2-CH_2-CH_2-CH_3$

hexane

Conc H_2SO_4: *compound dissolves*