X. Solution Concentration (Lecture) Answer Key

1. Percent by Mass: % w/w

a) A solution consists of 108 grams of ethyl alcohol, C_2H_5OH, and 45.7 grams water. Calculate the percent by mass (% w/w) ethyl alcohol. % w/w = Part/whole

$$\frac{108\,g\ C_2H_5OH}{108\,g\ C_2H_5OH + 45.7\,g\ H_2O} \times 100 = 70.26675\,\%$$

$$= \boxed{70.3\,\%\ w/w}$$

b) An aqueous solution is 17.3% w/w Na_2SO_4. Calculate the number of grams of solution which contains 9.23×10^4 grams Na_2SO_4.

i) IMPORTANT POINT: The given concentration is a CONVERSION FACTOR. Write 17.3% w/w Na_2SO_4 as a conversion factor now, and then solve the problem using dimensional analysis.

$$9.23 \times 10^4\,g\ Na_2SO_4 \times \frac{100\,g\ Solution}{17.3\,g\ Na_2SO_4} = 5.39306 \times 10^5\,g\ solution$$

$$= \boxed{5.39 \times 10^5\,g\ solution}$$

2. Molarity: Moles solute/liter solution

a) 31.8 grams of $CaCl_2$ were dissolved in water to form 908 mL of solution. Calculate the molarity of this solution.

$$\frac{31.8\,g\ CaCl_2}{908\,mL\ sol.} \times \frac{1\,mol\ CaCl_2}{110.984\,g\ CaCl_2} \times \frac{1000\,mL\ Sol.}{1\,L\ Sol.} = 0.3155592\ \frac{mols\ CaCl_2}{L}$$

$$= \boxed{0.316\ \frac{mols\ CaCl_2}{L}}$$

b) Calculate the number of grams of NaCl required to make 118 mL of .49M NaCl.

i) IMPORTANT POINT: As above, realize that the given molarity can be used as a conversion factor. As soon as you see it as a given in a problem, immediately think conversion factor. Write .49M NaCl as a conversion factor now.

$$118.\,mL\ Sol \times \frac{1\,L\ Sol}{1000\,mL\ Sol} \times \frac{0.49\,mols\ NaCl}{1\,L\ Sol} \times \frac{58.4428\,g\ NaCl}{1\,mol\ NaCl} = 3.379163\,g\ NaCl$$

$$= \boxed{3.4\,g\ NaCl}$$

c) Calculate the number of mL of .56M $Al_2(SO_4)_3$ needed to supply 73.2 grams of $Al_2(SO_4)_3$.

$$73.2\ g\ Al_2(SO_4)_3 \times \frac{1\ mol\ Al_2(SO_4)_3}{342.1508\ g\ Al_2(SO_4)_3} \times \frac{1\ L\ sol.}{0.56\ mols\ Al_2(SO_4)_3} \times \frac{1000\ mL\ Sol}{1\ L\ Sol} =$$

$$= 382.0371\ mL\ Sol = \boxed{3.8 \times 10^2\ mL\ Solution}$$

d) Concentrated hydrochloric acid has a density of 1.18 g/mL and is 36.0% by mass dissolved HCl. What is the molarity of the concentrated acid?

$$\frac{1.18\ g\ Sol.}{1\ mL\ Sol.} \times \frac{36.0\ g\ HCl}{100\ g\ Sol.} \times \frac{1\ mol\ HCl}{36.46094\ g\ HCl} \times \frac{1000\ mL\ Sol}{1\ L\ Sol} = 11.6508\ \frac{mols\ HCl}{L}$$

$$= \boxed{11.7\ \frac{mols\ HCl}{L}}$$

or just 11.7 M HCl

e) An ethanol solution has a density of .94 g/mL and consists of 6.2 grams of C_2H_5OH and 9.4 grams of water. Calculate the molarity of the ethanol.

$$\frac{0.94\ g\ Sol}{1\ mL\ Sol} \times \frac{6.2\ g\ C_2H_5OH}{15.6\ g\ Sol} \times \frac{1\ mole\ C_2H_5OH}{46.06904\ g\ C_2H_5OH} \times \frac{1000\ mL\ Sol}{1\ L\ Sol} = \frac{8.10935\ mol}{1\ L\ sol}$$

$$= \boxed{8.1\ \frac{mol\ C_2H_5OH}{L}}$$

f) A solution consisting of 14.0 grams of acetone, C_3H_6O, and 187 grams of water has a density of .901 g/mL. Calculate the molarity of the acetone.

$$\frac{0.901\ g\ Sol}{1\ mL\ Sol} \times \frac{14\ g\ C_3H_6O}{201\ g\ Sol} \times \frac{1\ mol\ C_3H_6O}{58.0768\ g\ C_3H_6O} \times \frac{1000\ mL\ Sol.}{1\ L\ Sol.} = 1.080573\ \frac{mols}{L}$$

$$= \boxed{1.1\ \frac{mols\ C_3H_6O}{L}}$$

187 g H_2O
\+ 14 g C_3H_6O
201 g Solution

g) A wine is 19.8% w/w ethyl alcohol, C_2H_5OH. The wine has a density of .963 g/mL. Calculate the molarity of the ethyl alcohol.

$$\frac{0.963\text{ g Solution}}{1\text{ mL Solution}} \times \frac{19.8\text{ g } C_2H_5OH}{100\text{ g Solution}} \times \frac{1\text{ mole } C_2H_5OH}{46.069\text{ g } C_2H_5OH} \times \frac{1000\text{ mL Sol.}}{1\text{ L Sol.}} = 4.138875\ \frac{\text{mol}}{\text{L}}$$

$$= \boxed{4.14\ \frac{\text{mol } C_2H_5OH}{\text{L}}}$$

h) Concentrated nitric acid is 71.0% w/w HNO_3. It has a molarity of 16.0M HNO_3. Calculate the density of the concentrated acid.

$$\frac{16.0\text{ mols } HNO_3}{1\text{ L sol}} \times \frac{63.01284\text{ g } HNO_3}{1\text{ mol } HNO_3} \times \frac{100\text{ g Sol}}{71.0\text{ g } HNO_3} \times \frac{1\text{ L sol}}{1000\text{ mL sol}} = 1.42001\text{ g/mL}$$

$$= 1.42\ \frac{\text{g sol}}{\text{mL sol}} = \boxed{1.42\text{ g/mL Solution}}$$

3. Dilution

a) Water is added to 200. mL of 5.00M KBr until the volume is 600. mL. Calculate the molarity of the diluted solution.

i) Key point: V times M = _________

$C_1 = 5.00M$
$V_1 = 200.\text{ mL}$
$C_2 = ?$
$V_2 = 600.\text{ mL}$

$$C_1V_1 = C_2V_2$$

$$C_2 = \frac{C_1V_1}{V_2} = \frac{5.00M \times 200.\text{ mL}}{600.\text{ mL}} = 1.66666\,M$$

$$= \boxed{1.67\,M\text{ KBr}}$$

b) An experiment requires 4.3 liters of .83M HCl. The lab only has a large quantity of 7.8M HCl. How many mL of the 7.8M HCl is required to make the 4.3 liters of .83M HCl?

$C_1 = 7.8M$
$V_1 = ?$
$C_2 = 0.83M$
$V_2 = 4.3L$

$$C_1V_1 = C_2V_2$$

$$V_1 = \frac{C_2V_2}{C_1} = \frac{0.83M \times 4.3L}{7.8M} = 0.457564\text{ L}$$

$$= \boxed{0.46\text{ L solution Required}}$$

4. Parts Per Million and Parts Per Billion

a) ppm = (part/total)10^6

ppb = (part/total)10^9

i) Be certain that the masses for part and total have the same units.

b) A 237 gram sample of lake water is found to contain .025 mg of Pb^{2+}. Calculate the concentration of lead(II) ion in ppm and ppb.

$$ppm = \frac{0.025 \text{ mg } Pb^{2+}}{237 \text{ g } H_2O} \times \frac{1 \text{ g } H_2O}{1000 \text{ mg } H_2O} \times 1{,}000{,}000 = 0.105485 \text{ ppm}$$

$$= \boxed{0.11 \text{ ppm}}$$

$$ppb = \frac{0.025 \text{ mg } Pb^{2+}}{237 \text{ g } H_2O} \times \frac{1 \text{ g } H_2O}{1000 \text{ mg } H_2O} \times 10^9 = 105.485 \text{ ppb}$$

$$= \boxed{110 \text{ ppb}}$$

c) Commercial table salt, NaCl, contains KI as a dietary supplement in order to prevent a person from developing thyroid problems (goiter). If 7.6 x 10^{-2} mg of KI is added per gram of the treated table salt, what is the concentration of KI in ppm?

$$ppm = \frac{7.6 \times 10^{-2} \text{ mg KI}}{1 \text{ g salt}} \times \frac{1 \text{ g KI}}{1000 \text{ mg KI}} \times 10^6 = \boxed{76 \text{ ppm KI}}$$

d) If the concentration of botulinum toxin in a mouse reaches about .05 ppb, the mouse will die. How many grams of toxin would kill a 30 gram mouse?

$$30 \text{ g mouse} \times \frac{0.05 \text{ g toxin}}{10^9 \text{ g mouse}} = 1.5 \times 10^{-9} \text{ g botulinum toxin}$$

if we take the 30g mouse to be 1 sig fig, then:

$$1.5 \times 10^{-9} \text{ g} = \boxed{2 \times 10^{-9} \text{ g toxin}}$$

Round even

5. Practice problems using concentrations as conversion factors.

a) Write the following concentrations as conversion factors:

i) 4.23% w/w KNO_3 $\frac{4.23\ g\ KNO_3}{100\ g\ solution}$

ii) 19.78% w/w CH_3OH $\frac{19.78\ g\ CH_3OH}{100\ g\ solution}$

iii) .097 ppm Hg in a sample of swordfish $\frac{0.097\ g\ Hg}{10^6\ g\ fish}$

iv) .0035 ppm bezene in well water. $\frac{0.0035\ g\ benzene}{10^6\ g\ H_2O}$

v) 3.84M K_3PO_4 $\frac{3.84\ mols\ K_3PO_4}{1\ L\ sol.}$

vi) 2.0M H_2SO_4 $\frac{2.0\ mols\ H_2SO_4}{1\ L\ sol.}$

b) Solve the following problems:

i) A solution is 3.23% w/w KBr. Calculate the number of grams of solution that would contain 4.78×10^3 grams KBr.

$$4.78 \times 10^3\ g\ KBr \times \frac{100\ g\ Solution}{3.23\ g\ KBr} = 147987.616\ g\ solution$$

$$= \boxed{148000\ g\ solution}$$

ii) A solution is .78M HCl. How many grams of HCl would be in 9.38×10^4 mL of this solution?

$$9.38 \times 10^4\ mL\ Sol. \times \frac{1\ L\ sol}{1000\ mL\ Sol} \times \frac{0.78\ Mols\ HCl}{1\ L\ Sol} \times \frac{36.458\ g\ HCl}{1\ mol\ HCl} = 2667.413\ g\ HCl$$

$$= \boxed{2700\ g\ HCl}$$

iii) A sample of soil is found to be contaminated with Pb, the concentration being about .035ppb Pb. How many mg of lead would be in a 7.3 pound sample of this soil?

$$7.3\ lbs\ soil \times \frac{453.6\ g\ Soil}{1\ lbs\ Soil} \times \frac{0.035\ g\ Pb}{10^9\ g\ Soil} \times \frac{1000\ mg\ Pb}{1\ g\ Pb} = 1.158948 \times 10^{-4}\ mg\ Pb$$

$$= \boxed{1.2 \times 10^{-4}\ mg\ Pb}$$