Worksheet 7

Solution Concentrations

Molarity (M): $M = \frac{\text{moles solute}}{\text{Liters solution}}$ **;** $M = \frac{\text{n}}{\text{V}}$

Molality (m): $m = \frac{\text{moles solute}}{\text{kg solvent}}$

Dilution: $C_1V_1 = C_2V_2$ Note: concentrations and volumes can be in any units, as long as both concentrations are in the same units as each other, and both volumes are in the same units as each other.

PPM: $\text{ppm} = \frac{\text{Mass of Solute}}{\text{Mass of Solution}} \times 1,000,000 \text{ ppm}$

and

ppm = grams (or kg, or lb, etc.) of solute in 1,000,000 grams (or kg, or lb., etc.) solution.

PPB: $\text{ppb} = \frac{\text{Mass of Solute}}{\text{Mass of Solution}} \times 1,000,000,000 \text{ ppb}$

and

ppb = grams (or kg, or lb, etc.) of solute in 1,000,000,000 grams (or kg, or lb., etc.) solution.

Problems

1.) What mass of magnesium nitrate, $Mg(NO_3)_2$, is needed to prepare 855 mL of a 0.575 *M* solution of magnesium nitrate?

First use the given volume and molarity to find the moles of magnesium nitrate needed. Then convert to grams using it's molar mass.

$$(0.855\ \text{L})\left(\frac{0.575\ \text{mol Mg(NO}_3)_2}{\text{L}}\right) = 0.496_1\ \text{moles Mg(NO}_3)_2$$

$$(0.496_1\ \text{mol Mg(NO}_3)_2)\left(\frac{148.313\ \text{g}}{\text{mol Mg(NO}_3)_2}\right) = 72.9_1\ \text{g Mg(NO}_3)_2$$

72.9 g $Mg(NO_3)_2$

2.) A 6.912–g sample of calcium sulfate dihydrate, $CaSO_4{\cdot}2H_2O$, is dissolved in 38.75 L of solution. Calculate the molarity of sulfate (SO_4^{2-}) in this solution.

First find moles of sulfate from the grams given. Then divide by the volume, in liters, to get the molarity.

$$(6.912\ \text{g CaSO}_4\cdot 2\text{H}_2\text{O})\left(\frac{1\ \text{mol}}{172.170\ \text{g CaSO}_4\cdot 2\text{H}_2\text{O}}\right) = 0.04014_6\ \text{mol CaSO}_4\cdot 2\text{H}_2\text{O}$$

$$(0.04014_6\ \text{mol CaSO}_4\cdot 2\text{H}_2\text{O})\left(\frac{1\ \text{mol SO}_4^{2-}}{1\ \text{mol CaSO}_4\cdot 2\text{H}_2\text{O}}\right) = 0.04014_6\ \text{mol SO}_4^{2-}$$

$$\frac{0.04014_6\ \text{mol SO}_4^{2-}}{38.75\ \text{L}} = 0.001036_0\ M$$

0.001036 M

3.) What mass of solute is contained in 149 mL of a 0.728 M ammonium nitrate, NH_4NO_3, solution?

Use the volume and molarity given to find moles of the solute. Then use it's molar mass to convert to grams.

$$(0.149\ \text{L})\left(\frac{0.728\ \text{mol NH}_4\text{NO}_3}{\text{L}}\right) = 0.108_4\ \text{mol NH}_4\text{NO}_3$$

$$(0.108_4\ \text{mol NH}_4\text{NO}_3)\left(\frac{80.043\ \text{g NH}_4\text{NO}_3}{1\ \text{mol NH}_4\text{NO}_3}\right) = 8.68_2\ \text{g NH}_4\text{NO}_3$$

8.68 g NH_4NO_3

4.) How many grams of bromide are there in 55.2 mL of a 0.449 M solution of gallium bromide?

$$GaBr_3$$

$$(0.0552\ \text{L})\left(\frac{0.449\ \text{mol GaBr}_3}{\text{L}}\right) = 0.0247_8\ \text{mol GaBr}_3$$

$$(0.0247_8\ \text{mol GaBr}_3)\left(\frac{3\ \text{mol Br}^-}{1\ \text{mol GaBr}_3}\right)\left(\frac{79.904\ \text{g Br}^-}{1\ \text{mol Br}^-}\right) = 5.94_1\ \text{g Br}^-$$

5.94 g Br^-

5.) What volume of 6.112 *M* nitric acid must be used to prepare 1.75 L of 0.850 M HNO_3?

This is a dilution equation problem where we are looking for V_1.

$$C_1V_1 = C_2V_2 \Rightarrow V_1 = \frac{C_2V_2}{C_1}$$

C_1 = 6.112 *M* C_2 = 0.850 *M* V_2 = 1.75 L

$$V_1 = \frac{(0.850\,M)\,(1.75\ \text{L})}{6.112\,M} = 0.243_3\ \text{L}$$

243 mL

6.) 1.50 mL of a 0.459 M solution of methyl salicylate acid is diluted with 11.25 mL of methylene chloride, forming solution A. Then 2.75 mL of solution A is diluted with 9.50 mL of methylene chloride, forming solution B. 5.25 mL of solution B is then diluted with 5.00 mL of methylene chloride to form solution C. What is the concentration of methyl salicylate in solution C?

This is a multi-step dilution equation problem. First find the concentration of solution A. Then use that as the initial concentration for the second dilution to find the concentration of solution B. Then that concentration is used as the initial concentration to find the concentration of solution C.

Solution A

$$C_1V_1 = C_2V_2 \Rightarrow C_2 = \frac{C_1V_1}{V_2}$$

C_1 = 0.459 *M* V_1 = 1.50 mL V_2 = 11.25 mL + 1.50 mL = 12.75 mL

$$C_2 = \frac{(0.459\,M)\,(1.50\ \text{mL})}{12.75\ \text{mL}} = 0.0540\,M$$

Solution B

C_1 = 0.0540 *M* V_1 = 2.75 mL V_2 = 2.75 mL + 9.50 mL = 12.25 mL

$$C_2 = \frac{(0.0540\,M)\,(2.75\ \text{mL})}{12.25\ \text{mL}} = 0.0121_2\,M$$

Solution C

$C_1 = 0.0121_2\ M$ $V_1 = 5.25$ mL $V_2 = 5.25$ mL + 5.00 mL = 10.25 mL

$$C_2 = \frac{(0.0121_2\ M)\,(5.25\text{ mL})}{10.25\text{ mL}} = 0.00620_9\ M$$

0.00621 M

7.) What is the molality of iron (III) chloride in a solution that is prepared by dissolving 17.339 g of iron (III) chloride in 454.2 g of water?

$FeCl_3$

First find moles of the solute. Then divide by the kg of the solvent.

$$\frac{17.339\text{ g FeCl}_3}{162.204\text{ g/mol}} = 0.10689_6\text{ mol FeCl}_3$$

$$\frac{0.10689_6\text{ mol FeCl}_3}{0.454.2\text{ kg}} = 0.2353_5\ \ m$$

0.2354 *m*

8.) A solution of copper (II) nitrate is prepared by dissolving 19.437 g of copper (II) nitrate in 399.4 g of water. Then 35.22 mL of the resulting solution is diluted to a final volume of 250.0 mL. What is the molality of copper (II) nitrate in the final solution?

$Cu(NO_3)_2$

Find the molality of the original solution first. Then use the dilution equation to find the molality of the final solution.

$$\frac{19.437\text{ g Cu(NO}_3)_2}{187.554\text{ g/mol}} = 0.10363_4\text{ mol Cu(NO}_3)_2$$

$$\frac{0.10363_4\text{ mol}}{0.3994\text{ kg}} = 0.2594_7\ m$$

$$C_1V_1 = C_2V_2 \Rightarrow C_2 = \frac{C_1V_1}{V_2}$$

$C_1 = 0.2594_7\ m$ $V_1 = 35.22$ mL $V_2 = 250.0$ mL

$$C_2 = \frac{(0.2594_7\ m)(35.22\text{ mL})}{250.0\text{ mL}} = 0.03655_4\ m$$

0.03655 *m*

9.) If your city reports that there are 18 ppb manganese (Mn) in your drinking water. The EPA recommends a maximum level of manganese in drinking water as 50 µg/L. What is the concentration of manganese in your drinking water in µg/L? Is it safe to drink?

We will assume that the density of the water is 1.00 g/mL. At anywhere close to room temperature, this is a good approximation to three significant figures. We can use dimensional analysis here.

$\underline{\hspace{2cm}}\mu\text{g Mn} =$

$$1\text{ L water}\left(\frac{1000\text{ mL water}}{1\text{ L water}}\right)\left(\frac{1.00\text{ g water}}{1\text{ mL water}}\right)\left(\frac{18\text{ g Mn}}{1\times10^{9}\text{ g water}}\right)\left(\frac{1\,\mu\text{g Mn}}{1\times10^{-6}\text{ g Mn}}\right)$$

$$= 18\,\mu\text{g Mn} \Rightarrow 18\,\frac{\mu\text{g}}{\text{L}}$$

As it turns out, µg/L is the same as ppb for water near room temperature. Yes, it is safe to drink your water.

18 µg/L, Yes

10.) If your drinking water has 15 ppb lead (the EPA action limit), how many grams of lead are there in a 12.0 oz (355 mL) glass of that water?

Dimensional analysis is the way to approach this one. 15 ppb lead is one conversion factor. Because we are given a volume of water, and need the mass of that water, we should assume that the density is 1.00 g/mL. This is a good assumption, to three significant figures.

$$\underline{\hspace{1cm}}\text{g Pb} = 355\text{ mL water}\left(\frac{1.00\text{ g water}}{1.00\text{ mL water}}\right)\left(\frac{15\text{ g Pb}}{1\times10^{9}\text{ g water}}\right) = 5.3_2\times10^{-6}\text{ g Pb}$$

5.3 x 10^{-6} g Pb, or 5.3 mg Pb

11.) How many ppm of nitrate, NO_3^-, are there in a solution that is prepared by dissolving 2.134 g of potassium nitrate in enough water to make 100. mL of solution, then diluting 2.00 mL of that solution to 500. mL?

First find mass of nitrate in 2.134 g of potassium nitrate, then we find the ppm nitrate in the original 100. mL of solution, then use the dilution equation to find the ppm nitrate in the final 500. mL of solution. Note that we will once more assume the density of the solution is that of water to three significant figures, 1.00 g/mL. That gives us the mass of the first solution as 100. g.

100. mL Solution

$$2.134 \text{ g KNO}_3 \left(\frac{62.004 \text{ g NO}_3^-}{101.102 \text{ g KNO}_3}\right) = 1.308_7 \text{ g NO}_3^-$$

$$\text{ppm NO}_3^- = \frac{1.308_7 \text{ g NO}_3^-}{100. \text{ g solution}} \times 1 \times 10^6 \text{ ppm} = 1.30_8 \times 10^4 \text{ ppm}$$

500. mL Solution

$$\text{C}_1\text{V}_1 = \text{C}_2\text{V}_2 \Rightarrow \text{C}_2 = \frac{\text{C}_1\text{V}_1}{\text{V}_2}$$

$C_1 = 1.30_8 \times 10^4$ ppm $\quad V_1 = 2.00$ mL $\quad V_2 = 500.$ mL

$$\text{C}_2 = \frac{\left(1.30_8 \times 10^4 \text{ ppm}\right)(2.00 \text{ mL})}{500. \text{ mL}} = 52.3_4 \text{ ppm NO}_3^-$$

52.3 ppm NO_3^-