**Answer Key for Problem Set Dealing with Concentration Units**

1 a. The formula for sodium sulfate is Na2SO4.

$$w/w\% Na\_{2}SO\_{4} = \frac{grams Na\_{2}SO\_{4}}{grams solution} x 100$$

The mass of solute is 15.0 g Na2SO4. The mass of solvent (water) is 400.0 g, so the mass of solution is:

15.0 g Na2SO4 + 400.0 g H2O = 415.0 g solution

$$w/w\% Na\_{2}SO\_{4} = \frac{15. 0 g Na\_{2}SO\_{4} }{415.0 g solution} x 100 = 3.61\% Na\_{2}SO\_{4}$$

 1 b. The molar mass of Na2SO4. must be calculated to find the moles of Na2SO4.

 Molar mass of Na2SO4. = 2 AW of Na + AW of S + 4 AW of O (where AW = atomic weight)

 = 2(22.99 g/mol) + 32.07 g/mol + 4(16.00 g/mol) = 142.05 g Na2SO4./mol Na2SO4.

 Find the moles of Na2SO4.:

$$15.0 g Na\_{2}SO\_{4} x \frac{1 mole Na\_{2}SO\_{4}}{142.05 g Na\_{2}SO\_{4}} = 0.106 mol Na\_{2}SO\_{4}$$

 Find the volume of solution in liters. Recall from part a, the mass of solution is 415.0g.

$$415.0 g solution x \frac{1 mL solution}{1.056 g solution} x \frac{1 L solution}{1000 mL solution} = 0.3930 L solution$$

 Calculate the molarity:

$$Molarity of Na\_{2}SO\_{4} = \frac{0.106 mol Na\_{2}SO\_{4}}{0.3930 L solution} = 0.270 M Na\_{2}SO\_{4} $$

1 c. The moles of Na2SO4 is already known from part b. Find the kilograms of solvent (water):

$$400.0 g H\_{2}O x \frac{1 kg H\_{2}O}{1000 g H\_{2}O} = 0.4000 kg H\_{2}O$$

 Calculate the molality of Na2SO4 :

$$molality of Na\_{2}SO\_{4} = \frac{0.106 mol Na\_{2}SO\_{4}}{0.4000 kg water} = 0.265 m Na\_{2}SO\_{4}$$

1 d. Calculate the parts per thousand of Na2SO4 from the mass of solute and mass of solution:

$$ppt Na\_{2}SO\_{4} = \frac{15.0 g Na\_{2}SO\_{4}}{415 g solution} x 1000 = 36.1 ppt Na\_{2}SO\_{4}$$

1 e. Parts per million may also be expressed as mg solute/L solution. In this case, converting the molarity to ppm will be the simplest route:

$$\frac{0.270 mol Na\_{2}SO\_{4}}{L solution} x \frac{2 mol Na^{+}}{1 mol Na\_{2}SO\_{4}} x \frac{22.99 g Na^{+}}{1 mol Na^{+}} x \frac{1000 mg Na^{+}}{1 g Na^{+}} = 1.24 x 10^{4} ppm Na^{+}$$

1 e. For the mole fraction of sulfate, we need to have:

$$mole fraction SO\_{4}^{2-} = \frac{mol SO\_{4}^{2-}}{mol SO\_{4}^{2-} + mol Na^{+} + mol H\_{2}O}$$

 Find the moles of Na+ :

$$0.106mol Na\_{2}SO\_{4} x \frac{2 mol Na^{+}}{1 mol Na\_{2}SO\_{4}} = 0.212 mol Na^{+}$$

 Find the moles of SO42- :

$$0.106 mol Na\_{2}SO\_{4} x \frac{1 mol SO\_{4}^{2-}}{1 mol Na\_{2}SO\_{4}} = 0.106 mol SO\_{4}^{2-}$$

 Find the moles of H2O:

$$400.0 g H\_{2}O x \frac{1 mol H\_{2}O}{18.02 g H\_{2}O} = 22.20 mol H\_{2}O$$

 Calculate the mole fraction of sulfate:

$$X of SO\_{4}^{2-} = \frac{0.106 mol SO\_{4}^{2-}}{0.212 mol Na^{+} + 0.106 mol SO\_{4}^{2-} + 22.20 mol H\_{2}O} = 0.00471$$

2 a. Assume exactly 1 liter (1000 mL) of solution, which is the quantity present in the denominator of the known concentration unit (molarity). This also means you have 12.0 mol HCl present. Convert the moles of HCl to a mass of HCl:

$$12.0 mol HCl x \frac{36.46 g HCl}{1 mol HCl} = 437.5 g HCl$$

 Find the mass of solution using the density of the solution:

$$1000 mL solution x \frac{1.107 g solution}{1 mL solution} = 1107 g solution$$

 Calculate the mass percent of HCl:

$$\frac{437.5 g HCl}{1107 g solution} x 100 = 39.5 \%HCl$$

2 b. Find the mass of solvent:

1107 g solution – 437.5 g HCl = 670 g H2O

 Convert the mass of solvent to kilograms:

$$670g H\_{2}O x \frac{1 kg H\_{2}O}{1000 g H\_{2}O} = 0.670 kg H\_{2}O$$

 Calculate the molality:

$$\frac{12.0 mol HCl}{0.670 kg H\_{2}O} = 17.9 m HCl$$

2 c. Find the moles of H2O:

$$670 g H\_{2}O x \frac{1 mol H\_{2}O}{18.02 g H\_{2}O} = 37.2 mol H\_{2}O$$

 Calculate the mole fraction of HCl:

$$X of HCl = \frac{12.0 mol HCl}{12.0 mol HCl + 37.2 mol H\_{2}O} = 0.244$$

3 a. Assume exactly 1 kg (1000 g) of water (solvent), which is the quantity present in the denominator of the known concentration unit (molality). This also means you have 0.300 mol Ca(NO3)2.

 To find the mass of calcium nitrate, you need the molar mass of Ca(NO3)2:

 Molar mass of Ca(NO3)2 = AW of Ca + 2 AW of N + 6 AW of O (where AW = atomic weight)

 = 40.08 g/mol + 2(14.01 g/mol) + 6(16.00 g/mol) = 164.10 g Ca(NO3)2/mol Ca(NO3)2

 Calculate the mass of Ca(NO3)2 :

$$0.300 mol Ca(NO\_{3})\_{2} x \frac{164.10 g Ca(NO\_{3})\_{2}}{1 mol Ca(NO\_{3})\_{2}} = 49.2 g Ca(NO\_{3})\_{2}$$

 Find the mass of solution:

mass of solution = 49.2 g Ca(NO3)2 + 1000.0 g H2O = 1049.2 g solution

 Calculate the mass percent of Ca(NO3)2 :

$$\frac{49.2 g Ca(NO\_{3})\_{2}}{1049.2 g solution} x 100 = 4.69 \%Ca(NO\_{3})\_{2}$$

3 b. To find the mass of nitrate ion, you need the molar mass of nitrate ion (NO3¯ ):

 Molar mass of NO3¯ = AW of N + 3 AW of O (where AW = atomic weight)

 = 14.01 g/mol + 3(16.00 g/mol) = 62.01 g NO3¯/mol NO3¯

 Calculate the mass of nitrate ion:

$$0.300 mol Ca(NO\_{3})\_{2} x \frac{2 mol NO\_{3}^{-}}{1 mol Ca(NO\_{3})\_{2}} x \frac{62.01 g NO\_{3}^{-}}{1 mol NO\_{3}^{-}} = 37.2 g NO\_{3}^{-}$$

 Calculate the mass percent of nitrate ion:

$$\frac{37.2 g NO\_{3}^{-}}{1049.2 g Ca(NO\_{3})\_{2}} x 100 = 3.55 \%NO\_{3}^{-}$$

3 c. Find the mass of calcium ion:

$$0.300 mol Ca(NO\_{3})\_{2} x \frac{1 mol Ca^{2+}}{1 mol Ca(NO\_{3})\_{2}} x \frac{40.08 g Ca^{2+}}{1 mol Ca^{2+}} = 12.0 g Ca^{2+}$$

 Calculate the mass percent of calcium ion:

$$\frac{12. 0 g Ca^{2+}}{1049.2 g Ca(NO\_{3})\_{2}} x 100 = 1.14 \%Ca^{2+}$$

 Notice how the sum of %Ca2+ and %NO3¯ sum to the %Ca(NO3)2.

3 d. Convert the mass of solution to volume of solution in liters:

$$1049.2 g solution x \frac{1 mL solution}{1.009 g solution} x \frac{1 L solution}{1000 mL solution} = 1.040 L solution$$

 Calculate the molarity:

$$\frac{0.300 mol Ca(NO\_{3})\_{2}}{1.040 L solution} = 0.288 M Ca(NO\_{3})\_{2}$$

3 e. Calculate the molarity of nitrate ions:

$$\frac{0.288 mol Ca(NO\_{3})\_{2}}{1 L solution} x \frac{2 mol NO\_{3}^{-}}{1 mol Ca(NO\_{3})\_{2}} = 0.576 M NO\_{3}^{-}$$

3 f. Find the moles of calcium ion:

$$0.300 mol Ca(NO\_{3})\_{2} x \frac{1 mol Ca^{2+}}{1 mol Ca(NO\_{3})\_{2}} = 0.300 mol Ca^{2+}$$

 Find the moles of nitrate ion:

$$0.300 mol Ca(NO\_{3})\_{2} x \frac{2 mol NO\_{3}^{-}}{1 mol Ca(NO\_{3})\_{2}} = 0.600 mol NO\_{3}^{-}$$

 Find the moles of water:

$$1000 g H\_{2}O x \frac{1 mol H\_{2}O}{18.02 g H\_{2}O} = 55.49 mol H\_{2}O$$

 Calculate the mole fraction of calcium ion:

$$\frac{0.300 mol Ca^{2+}}{0.300 mol Ca^{2+} + 0.600 mol NO\_{3}^{-} + 55.49 mol H\_{2}O} = 0.00532$$

3 g. Calculate the mole fraction of nitrate ion:

$$\frac{0.600 mol NO\_{3}^{-}}{0.300 mol Ca^{2+} + 0.600 mol NO\_{3}^{-} + 55.49 mol H\_{2}O} = 0.0106$$

4. Recall that parts per million may also be expressed as mg solute/liter of solution or mg solute per kilograms solution. Either case will work here because the density of the solution is given as 1.00 g/mL. Assume exactly 1 liter of solution (1000 g solution) so that the mass of solute (25.0 mg of magnesium ion) is known.

4 a. Convert milligrams of magnesium ion to grams magnesium ion:

$$25.0 mg Mg^{2+} x \frac{1 x 10^{-3}g Mg^{2+}}{1 mg Mg^{2+}} = 0.0250 g Mg^{2+}$$

 Calculate the w/w% magnesium ion:

$$\frac{0.0250 g Mg^{2+}}{1000 g solution} x 100 = 0.00250 \%Mg^{2+}$$

4 b. Find the number of grams of chloride ion keeping in mind the chemical formula of magnesium chloride is MgCl2:

$$0.0250 g Mg^{2+} x \frac{1 mol Mg^{2+}}{24.30 g Mg^{2+}} x \frac{2 mol Cl^{-}}{1 mol Mg^{2+}} x \frac{35.45 g Cl^{-}}{1 mol Cl^{-}} = 0.0729 g Cl^{-}$$

 Calculate the w/w% of Cl¯:

$$\frac{0.0729 g Cl^{-}}{1000 g solution} x 100 = 0.00729 \%Cl^{-}$$

4 c. Find the number of grams of magnesium chloride:

$$0.0250 g Mg^{2+} x \frac{1 mol Mg^{2+}}{24.30 g Mg^{2+}} x\frac{1 mol MgCl\_{2}}{1 mol Mg^{2+}} x \frac{95.20 g MgCl\_{2}}{1 mol MgCl\_{2}} = 0.0979 g MgCl\_{2}$$

 Calculate the w/w % MgCl2:

$$\frac{0.0929 g MgCl\_{2}}{1000 g solution} x 100 = 0.00929 \%MgCl\_{2}$$

4 d. Find the moles of magnesium chloride:

$$0.0979 g MgCl\_{2} x \frac{1 mol MgCl\_{2}}{95.20 g MgCl\_{2}} = 0.00103 mol MgCl\_{2}$$

 Calculate the molarity of $MgCl\_{2}:$

$$\frac{0.00103 mol MgCl\_{2}}{1 L solution} = 0.00103 M MgCl\_{2}$$

4 e. Calculate the molarity of magnesium ions:

$$\frac{0.00103 mol MgCl\_{2}}{1 L solution} x \frac{1 mol Mg^{2+}}{1 mol MgCl\_{2}} = 0.00103 M Mg^{2+}$$

4 f. Calculate the molarity of chloride ions:

$$\frac{0.00103mol MgCl\_{2}}{1 L solution} x \frac{2mol Cl^{-}}{1 mol MgCl\_{2}} = 0.00206 mol Cl^{-}$$

4 g. Find the mass of water:

 1000 g solution – 0.0979 g MgCl2 = 999.9021 g H2O

 Convert this mass to kilograms:

$$999.9021 g H\_{2}O x \frac{1 kg H\_{2}O}{1000 g H\_{2}O} = 0.9999021 kg H\_{2}O$$

 Calculate the molality of MgCl2:

$$\frac{0.00103 mol MgCl\_{2}}{0.9999021 kg H\_{2}O} = 0.00103 m MgCl\_{2}$$