Chem 151 Drilling Question Set #2
Mole and Molarity

1. a. What is the molar mass of copper(II) nitrate?

molar mass of $Cu(NO_3)_2$ = 63.5 + 2 (14.0 + 3 x 16.0) = 187.5 g/mole

b. What is the mass, in grams, of 0.120 moles of copper(II) nitrate?

Mass = (0.120 mole)(187.5 g/mol) = 22.5 mole

c. How many nitrogen atoms are present in 1.25 mg of copper(II) nitrate? (1 mg = 1 x 10^{-3} g)

$$(1.25\times10^{-3}\ g)(\frac{1\ mol\ Cu(NO_3)_2}{187.5\ g})(\frac{2\ mol\ N\ atoms}{1\ mol\ Cu(NO_3)_2}) = 1.33\times10^{-5}\ moles\ N\ atoms$$

Note that "mole" is a unit of number.

2. Calculate the mass in grams of each of the following:

a. 0.0287 mole of aspirin, $C_9H_8O_4$

Molar mass of aspirin = 180 g/mol

Mass of aspirin = (0.287 mol)(180 g/mol) = 5.17 g

b. 1.75 x 10^{21} molecules of ozone

molar mass of O_3 = 3 x 16.0 g/mol = 48.0 g

Mass = $(1.75\times10^{21}\ molecules)(\frac{1\ mole}{6.022\times10^{23}\ molecules})(\frac{48.0\ g}{1\ mol}) = 0.139g$

c. two molecules of cholesterol, $C_{27}H_{46}O$

molar mass of cholesterol = 386 g/mol

Mass = $(2\ molecules)(\frac{1\ mole}{6.022\times10^{23}\ molecules})(\frac{386\ g}{1\ mol}) = 1.28\times10^{-21}\ g$

3. Laughing gas, N_2O, can be made by the thermal decomposition of ammonium nitrate according to the below equation. How many grams of laughing gas can be obtained from 18.5 g of ammonium nitrate?

$$NH_4NO_3 \rightarrow N_2O + 2\ H_2O$$

$$(18.5\ g\ NH_4NO_3)(\frac{1\ mol\ NH_4NO_3}{80.0\ g})(\frac{1\ mol\ N_2O}{1\ mol\ NH_4NO_3})(\frac{44.0\ g}{1\ mol\ N_2O}) = 10.2\ g$$

Do not just focus on the cancellation of units in your calculation. Instead, you should focus on the method. First, the amount of reactant is converted to mole. Then, the mole of reactant is related to the mole of product using the reaction equation. Last the mole of product is converted to the mass of product.

4. A copper wire weighed 3.25 g is dissolved in nitric acid according to the reaction equation:

$Cu + 4\ HNO_3 \rightarrow Cu(NO_3)_2 + 2\ NO_2 + 2\ H_2O$

Sodium hydroxide is added to the above solution containing copper(II) nitrate and $Cu(OH)_2$ is formed.

$Cu(NO_3)_2 + 2\ NaOH \rightarrow Cu(OH)_2 + 2\ NaNO_3$

The solution is then heated and $Cu(OH)_2$ decomposes to CuO. $Cu(OH)_2 \rightarrow CuO + H_2O$

How many grams of CuO can be produced by this process?

Since the above reactions has no copper by-products, all copper metal is converted to CuO. Since one Cu makes one CuO, the mass of CuO produced by this process is:

Mass of CuO = $(3.25\ g\ Cu)(\frac{1\ mol\ Cu}{63.55\ g})(\frac{1\ mol\ CuO}{1\ mol\ Cu})(\frac{79.55\ g}{1\ mol\ CuO}) = 4.07\ g\ CuO$

5. A cobalt compound, $[Co(NH_3)_6]Cl_3$ is prepared by the following reaction:

$CoCl_2 \cdot 6H_2O + \frac{1}{2}\ H_2O_2 + NH_4Cl + 5\ NH_3 \rightarrow [Co(NH_3)_6]Cl_3 + 7\ H_2O$

How many grams of $[Co(NH_3)_6]Cl_3$ can be produced from 0.123 mole of NH_3 if the quantity of the other reactants are more than sufficient and the reaction goes to completeness?

Molar mass of $[Co(NH_3)_6]Cl_3$ = 267.5 g/mol

First, find out how many moles of $[Co(NH_3)_6]Cl_3$ can be produced from 0.123 mole NH_3.

Moles of $[Co(NH_3)_6]Cl_3$ = $(0.123\ mol\ NH_3)(\frac{1\ mol\ [Co(NH_3)_6]Cl_3}{5\ mol\ NH_3}) = 0.0246\ mol$

Mass of $[Co(NH_3)_6]Cl_3$ = (0.0246 mol)(267.5 g/mol) = 6.58 g

6. Glucose can be converted into ethanol and carbon dioxide by fermentation. If the reaction goes to completion, how many liters of ethanol can be produced from 500. g of glucose? Density of ethanol is 0.789 g/mL.

$C_6H_{12}O_6 \rightarrow 2\ C_2H_5OH + 2\ CO_2$

Molar mass of glucose = 180 g/mol Molar mass of ethanol = 46.0 g/mol

Mass of ethanol can be produced

= $(500\ g\ glucose)(\frac{1\ mol\ glucose}{180\ g})(\frac{2\ mol\ ethanol}{1\ mol\ glucose})(\frac{46.0\ g}{1\ mol\ ethanol}) = 256\ g\ ethanol$

Volume of ethanol = $(256\ g)(\frac{1\times10^{-3}\ L}{0.789\ g}) = 0.324\ L$

7. The molecular formula of the iron core in ferritin is $[FeO(OH)]_8FeO(H_2PO_4)$. What is the molarity of Fe^{3+} ions if 1.00 mg of the iron core dissolves in acid to make 500. mL of solution?

Molar mass of $[FeO(OH)]_8FeO(H_2PO_4)$= 879.7 g/mol

Moles of $[FeO(OH)]_8FeO(H_2PO_4)$ = $(1.00\,mg)(\frac{1\,g}{1000\,mg})(\frac{1\,mol}{879.7\,g}) = 1.14\times10^{-6}\ mol$

Moles of Fe^{3+}= $(1.14\times10^{-6}\ mol)(\frac{9\ mol\ Fe^{3+}}{1\ mol\ [FeO(OH)]_8FeO(H_2PO_4)}) = 1.02\times10^{-5}\ mol\ Fe^{3+}$

Molarity of Fe^{3+} = $\frac{1.02\times10^{-5}\ mol}{0.500\ L} = 2.05\times10^{-5}\ mol/L = 2.05\times10^{-5}\ M$

8. A solution containing NaCl, $MgCl_2$, and $AlCl_3$. Given that the molarity of chloride ions in the solution is 1.00 M, the molarity of Na^+ and Mg^{2+} is 0.200 M and 0.300 M respectively. What is the molarity of Al^{3+} in the solution?

Let the total volume of solution be 1.00 L.

Since the total charges of the cations and the charges of the anions must be balanced, we have the following relationship:

Moles of Cl^- ions = 1(moles of Na^+) + 2(moles of Mg^{2+}) + 3(moles of Al^{3+})

Thus, we have: 1.00 mol = 0.200 mol + 0.600 mol + 3 (moles of Al^{3+})

Moles of Al^{3+} = $\frac{1}{3}(1.00 - 0.200 - 0.600) = 0.067\ mol$

Since the volume is assumed as 1.00 L, Molarity of Al^{3+} = 0.067 mol/L = 0.067 M

9. 40.00 mL of 0.300 M sodium sulfate, Na_2SO_4, solution is added to 70.00 mL of 0.200 M aluminum sulfate, $Al_2(SO_4)_3$, solution. (No reaction occurs.)

a) Calculate the molarity of the sulfate ions in the resultant solution.

Moles of SO_4^{2-} = (0.300 mol/L)(0.0400 L) + 3(0.200 mol/L)(0.0700 L) = 0.0540 mol

Volume of resultant solution = 40.00 mL + 70.00 mL = 110.00 mL = 0.11000 L

Molarity of SO_4^{2-} in solution = $\frac{0.0540\ mol}{0.11000\ L} = 0.491\ M$

b) Calculate the number of moles of barium ions needed in order to precipitate all the sulfate ions from the above solution.

The formula of barium sulfate is $BaSO_4$. Thus, one Ba^{2+} needs one SO_4^{2-}.

Moles of Ba^{2+} needed = moles of SO_4^{2-} in solution = 0.0540 mol

c) If the source of barium ions is a 0.150M barium chloride solution, calculate the volume of the barium chloride solution needed in order to precipitate all the sulfate ions from the solution.

Volume of $BaCl_2$ solution needed

$$= (0.0540\ mol\ Ba^{2+}\ needed)(\frac{1\ mol\ BaCl_2}{1\ mol\ Ba^{2+}})(\frac{1\ L\ solution}{0.150\ mol\ BaCl_2}) = 0.360\ L$$

10. 255 mL of 0.100 M nitric acid is added to 745 mL of 0.200 M nitric acid. What is the molarity of nitric acid in the resultant solution?

Total moles of HNO_3 = (0.100 mo/L)(0.255 L) + (0.200 mol/L)(0.745 L) = 0.1745 mol

Total volume of solution = 255 mL + 745 mL = 1000. mL = 1.000 L

Molarity of HNO_3 = $\dfrac{0.1745\ mole}{1.000\ L}$ ***= 0.1745 M***

11. The concentrated hydrochloric acid in the stockroom is 36.0% HCl by mass. Given that the density of this acid is 1.18 g/mL.

a) How many gram of HCl in 800. mL of this acid?

Grams of HCl = $(800.\ mL\ solution)(\dfrac{1.18\ g}{1\ mL})(36.0\%) = 340.\ g$

b) What is the molarity of this acid?

Moles of HCl in acid = $(340.g)(\dfrac{1\ mol}{36.46\ g}) = 9.33\ mol$

Molarity of HCl in solution = $\dfrac{9.33\ mol}{0.0800\ L} = 11.6\ M$

12. If 70.0 mL of the hydrochloric acid in Question 10 is diluted to 100. mL, what is the molarity of HCl in the diluted solution?

When a solution is diluted by adding water, the number of moles of solute in the solution remains unchanged. Therefore we have the equation:

$$M_{dilute}\ V_{dilute} = M_{concentrated}\ V_{concentrated}$$

Applying the equation to the problem, $M_{conc} = 11.6\ M$

$V_{conc} = 70.0\ mL$

$M_{dil} = ?$

$V_{dil} = 100.\ mL$

$$M_{dil} = \frac{(11.6\ M)(70.0\ mL)}{100.\ mL} = 8.16\ M$$