Nuggets: Molarity, Dilutions, Stoichiometry with M (Titrations); Enthalpy of a reaction (proportionality calculations)

MOLARITY – concentration of solutions; abbreviated as M (pronounced “molar”); [X+] – the square brackets indicates the concentration of X+ in molarity

\[ M = \frac{\text{moles of solute}}{\text{L of solution}} \]

Solute: The chemical that is dissolved into the solvent

Solvent: The liquid that the solute is dissolved into (usually water)

Solution: Solvent + Solute

Typical types of Problems:

1. “Simple” Molarity Problems: Use: \( M = \frac{x \text{ mol}}{V \text{ L}} \) (How to ID problem: Contains 1 chemical and 1 concentration)

Example 1: How many grams NaCl are needed to prepare 450ml of a 0.150M NaCl solution?

Answer 1: 3.9g NaCl \( \rightarrow \) need to use \( M = \text{mol/L} \)

\[ M = 0.150 \text{mol/L}; V = 450 \text{ml} \times (1 \text{L/1000ml}) = 0.450 \text{L}; x = \text{m} \]

\[ 0.150 \text{mol/L} = \frac{x}{0.450 \text{L}}; x = 0.0675 \text{mol NaCl} \]

Example 2: What is the concentration of NH\(_4^+\) when 3.50grams (NH\(_4\))\(_2\)S are added to 750. ml of water?

Answer 2: 0.136M NH\(_4^+\) \( \rightarrow \) need to use \( M = \text{mol/L} \) but there will be an extra step for this problem;

To solve need to do this calculation: \([\text{NH}_4^+] = \frac{\text{mol NH}_4^+}{\text{L of solution}}\)

\[ \text{mol NH}_4^+ = \left(3.50 \text{g (NH}_4\text{)}_2\text{S}\right) \left(\frac{1 \text{ mol (NH}_4\text{)}_2\text{S}}{68.73 \text{ g (NH}_4\text{)}_2\text{S}}\right) = 0.0517 \text{ mol NH}_4^+ \]

\[ [\text{NH}_4^+] = \frac{0.1018 \text{ mol NH}_4^+}{0.750 \text{ L solution}} = 0.1357 \text{ M NH}_4^+ = 0.136 \text{ M NH}_4^+ \]

2. Dilution Problems (How to ID problem: Contains 1 chemical with 2 concentrations)

Use: \( M_1 \times V_1 = M_2 \times V_2 \) (this is for dilutions; not reactions)

where \( M_1 \) and \( M_2 \) are the molarities of the initial and final solutions, respectively;

\( V_1 \) and \( V_2 \) are the volumes of the initial and final solutions, respectively; \( V_2 = V_1 \) + water added

Example 3: How many milliliters of 12.0M HCl stock solution is needed to prepare 1250mL of a 0.150M HCl solution?

Answer 3: 15.6ml \( \rightarrow \) need to use \( M_1 \times V_1 = M_2 \times V_2 \)

(a “stock solution” is a concentrated solution that is kept in the stockroom and is used to prepare dilute solutions)

\( M_1 = 12.0 \text{M}; V_1 = 1.25 \text{L}; M_2 = 0.150 \text{M}; V_2 = x \)

\[ 0.150 \text{mol/L}(1250 \text{ml}) = (12.0 \text{mol/L})(x \text{ ml}) \] (V\(_1\) and V\(_2\) can be in L or in ml; they must simply be the same units)

\[ x = 15.63 \text{ml} = 15.6 \text{ ml} \]

3. Stoichiometric Molarity Problems (use flowchart) (How to ID problem: Contains 2 chemicals reacting; these problems are sometimes called titrations, neutralizations, and may also have the term “equivalence point” in them)
Example 4: If it required 27.5ml of a 0.150M HCl solution to neutralize 15.5ml of Ba(OH)$_2$, what was the original concentration of the Ba(OH)$_2$?

Answer 4: 0.133M Ba(OH)$_2$  (2 chemicals → stoichiometric problem → M$_A$ → M$_B$ question (3 steps from the above flow chart))

Step 1: convert M$_A$ to mol A: M$_{HCl}$ = mol$_{HCl}$/L$^1$H$^1$; mol$_{HCl}$ = M x L = 0.150M/(27.5ml)(1L/1000ml) = 0.004125mol HCl

Step 2: convert mol HCl to mol Ba(OH)$_2$ using a balanced rxn;

\[
\frac{0.004125\text{mol HCl}}{2\text{mol HCl}} = 0.0020625\text{mol Ba(OH)}_2
\]

[hint: the stoichiometric ratio between an acid and base can be determined by inspection without writing the reaction; the ratio must be: 1 H$^+$ to 1 OH$^-$ or in other words, the same number of H$^+$ and OH$^-$; since HCl has 1 H$^+$ and Ba(OH)$_2$ has 2 OH$^-$, the common factor for these two numbers is 2; so there needs to be 2 HCl (2 H$^+$) and 1 Ba(OH)$_2$ (2 OH$^-$):

\[2\text{HCl(aq)} + \text{Ba(OH)}_2 \rightarrow 2\text{H}_2\text{O(l)} + \text{BaCl}_2(\text{aq})\]

Step 3: calculate the concentration using M$_{Ba(OH)}_2 = \frac{\text{mol}_{Ba(OH)}_2}{\text{L Ba(OH)}_2}$;

\[
[\text{Ba(OH)}_2] = \frac{0.0020625\text{mol Ba(OH)}_2}{(15.5\text{ml})(1\text{L}/1000\text{ml})} = 0.1331\text{M Ba(OH)}_2 = \textbf{0.133M Ba(OH)}_2
\]

ENERGY (skip if not covered)

Units of heat = J (joules) (J = kg (m$^2$/s$^2$)

Enthalpy = H; Change in enthalpy = \(\Delta H\);

Change in Enthalpy = \(\Delta H\) = heat of the reaction (at constant pressure)

Sign of \(\Delta H\): \(\Delta H < 0\) (-) → endothermic; energy is \textit{released} from the system – solution feels warm

\(\Delta H > 0\) (+) → exothermic; energy is \textit{absorbed} by the system – solution feels cool

ENTHALPY CHANGES FOR A CHEMICAL REACTION (skip if not covered) – scaling a reaction up or down

Example 5: How much heat is released when 16.0g O$_2$ reacts in this reaction: 2CuS + 3O$_2$ → 2CuO + 2SO$_2$ \(\Delta_h = -193\text{ kJ/mol}\)

Answer 5: -32.2kJ

scaling up: 16gO$_2$ \(\left(\frac{1\text{mol O}_2}{32\text{g O}_2}\right)\left(\frac{-193\text{kJ}}{3\text{mol O}_2}\right) = -32.2\text{kJ}\)

The conversion factor: \(\frac{-193\text{kJ}}{3\text{mol O}_2}\) comes from the balanced chemical reaction

can also be done as a proportionality: \(\frac{3\text{mol O}_2}{-193\text{kJ}} = \frac{16.0\text{g O}_2}{x}\) (a proportionality is: “3mol O$_2$ is to -193kJ as 16g O$_2$ is to $x$”);

can change to the same units (both grams or both moles): \(\frac{3\text{mol O}_2}{-193\text{kJ}} = \frac{0.500\text{mol O}_2}{x}\); cross multiply: 3x = -96.5kJ; x = -32.2kJ

Example 6: When 12.5g Fe is reacted in the following reaction 19.9kJ are \textit{evolved}. What is the enthalpy of reaction, \(\Delta_h\) for the reaction?

\(3\text{Fe(s)} + 2\text{O}_2(\text{g}) \rightarrow \text{Fe}_3\text{O}_4(\text{s})\)

Answer 6: -267kJ/mol

scaling up: 3mol Fe \(\left(\frac{55.85\text{g Fe}}{1\text{mol Fe}}\right)\left(\frac{-19.9\text{kJ}}{12.5\text{g Fe}}\right) = -266.7\text{kJ} = \Delta_h\)

can also be done as a proportionality: \(\frac{12.5\text{g Fe}}{-19.9\text{kJ}} = \frac{3\text{mol Fe}}{x}\); \(\frac{0.2238\text{mol Fe}}{-19.9\text{kJ}} = \frac{3\text{mol Fe}}{x}\); 0.2238x = -59.7; x = -266.8kJ/mol = \(\Delta_h\)

1. I. What is the concentration of HCl when 1.75g HCl is dissolved in water to a total volume of 250.ml?
II. a. What is the concentration of Na$_3$PO$_4$ when 1.50g of Na$_3$PO$_4$ is dissolved in to a total volume of 725ml?

b. What is the Na$^+$ concentration?   c. What is the PO$_4^{3-}$ concentration?

2. I. If the concentration of Na$_2$SO$_4$ is 0.15M, what is the concentration of Na$^+$?
II. If the concentration of (NH$_4$)$_3$AsO$_4$ is 0.50M, what is the concentration of AsO$_4^{3-}$? What is the concentration of NH$_4^{+}$?
3. I. How many grams of NaOH are there in 55ml of a 0.15M NaOH solution?
II. How many grams of HCl must be added to yield a 150.ml solution with a \([H^+]=3.16 \times 10^{-3}\) M?
III. How many milliliters of 0.515M Ba(NO\(_3\))\(_2\) solution will provide 1.25grams of Ba(NO\(_3\))\(_2\)?

4. I. You are asked to produce 250.ml of 0.450M Na\(_2\)S. How many milliliters of 1.25M Na\(_2\)S are required?
II. How much water must be added to a 2.15M HNO\(_3\) solution to obtain 1.50L of a 0.750M HNO\(_3\) solution?
III. To what final volume should 25ml of 2.4M K\(_2\)Cr\(_2\)O\(_7\) be diluted to give a solution that is 0.10M K\(_2\)Cr\(_2\)O\(_7\)?

5. I. How many milliliters of 0.10M NaOH solution is required to neutralized 50. ml of a 0.20M HCl solution?
II. How many milliliters of 0.75M H\(_3\)C\(_6\)H\(_5\)O\(_7\), citric acid, solution is required to neutralized 50. ml of a 0.50M Ba(OH)\(_2\) solution? (Note: citric acid is a triprotic acid; i.e., having 3 H\(^+\)’s)

6. I. If 26.3ml of 0.100M H\(_2\)SO\(_4\) is titrated with 34.6ml of NaOH solution, what was the concentration of the NaOH solution.
II. If it takes 12.5ml of a 0.400M HCl solution to neutralize 25.0ml of a Ca(OH)\(_2\) solution in a titration, what was the concentration of the Ca(OH)\(_2\) solution?
III. If it takes 20.0ml of a 0.100M triprotic acid solution, H\(_3\)A, to neutralize 50.0ml of a Ba(OH)\(_2\) solution in a titration, what was the concentration of the Ba(OH)\(_2\) solution?

7. I. How many grams of Na\(_2\)S are needed to completely precipitate 355ml of a 0.275M solution of Al(NO\(_3\))\(_3\)?
   \[2\text{Al(NO}_3\text{)}_3 + 3\text{Na}_2\text{S} \rightarrow \text{Al}_2\text{S}_3 + 6\text{NaNO}_3\]
II. What volume of 0.100M HCl solution is required to react with 5.00g of NaHCO\(_3\) in the following reaction?
   \[\text{HCl} + \text{NaHCO}_3 \rightarrow \text{H}_2\text{O} + \text{CO}_2 + \text{NaCl}\]

8. a. 450.ml of 1.25M Pb(NO\(_3\))\(_2\)(aq) solution was mixed with 250.ml of a 2.50M KI(aq) solution and yields a solid. Write the balanced molecular reaction.
b. How many moles of the solid product was formed?
c. Which reactant was the limiting reactant?
d. How many moles of the excess reactant is left over?
e. What is the concentration of the excess reactant?
f. What ions are present at the end of the reaction?

9. It is found that 56.9ml of a 0.250M LiOH solution was needed to complete react with 1.15 grams of a monoprotic acid, HA. What is the molar mass of this unknown acid?

Intro to Energy (skip if not covered)

10. Use the reaction shown to answer the following questions.
   \[\text{P}_4\text{S}_3(s) + 8\text{O}_2(g) \rightarrow \text{P}_4\text{O}_{10}(s) + 3\text{SO}_2(g)\]
   \[\Delta H^\circ = -3677\text{kJ}\]
a. How much heat would be released if 5.000mol \(\text{P}_4\text{S}_3(s)\) were consumed?
b. How much heat would be released if 25.00g \(\text{O}_2(g)\) were consumed?

11. Use the reaction shown to answer the following questions.
   \[\text{C}_3\text{H}_8(g) + 5\text{O}_2(g) \rightarrow 3\text{CO}_2(g) + 4\text{H}_2\text{O}(g)\]
   \[\Delta H^\circ = -2044\text{kJ}\]
a. How much heat would be released if 10.0mol \(\text{O}_2(g)\) were consumed?
b. How much heat would be released if 100.0g \(\text{CO}_2(g)\) were produced?

12. Is the process to boil water an endothermic or exothermic process?
ANSWERS

I. \([\text{HCl}] = 0.192\text{M}\) \{1.75g HCl \(\frac{1\text{mol HCl}}{36.45\text{g HCl}} = 0.04801\text{mol HCl} ; [\text{HCl}] = \frac{0.04801\text{mol HCl}}{0.250\text{L solution}} = 0.1920\text{M HCl}\}\\

II. a. \([\text{Na}_3\text{PO}_4] = 1.26 \times 10^{-2}\text{M}\) \{1.50g Na$_3$PO$_4$ \(\frac{1\text{mol Na}_3\text{PO}_4}{163.94\text{g Na}_3\text{PO}_4} = 0.009150\text{mol Na}_3\text{PO}_4 ; [\text{Na}_3\text{PO}_4] = \frac{0.009150\text{mol Na}_3\text{PO}_4}{0.725\text{L solution}} = 0.01262\text{M Na}_3\text{PO}_4 \}\\

\[\text{b. } [\text{Na}^+] = 3.79 \times 10^{-2}\text{M}\] \{0.009150mol Na$_3$PO$_4$ \(\frac{3\text{mol } \text{Na}^+}{1\text{mol Na}_3\text{PO}_4} = 0.02745\text{mol } \text{Na}^+ ; [\text{Na}^+] = \frac{0.02745\text{mol } \text{Na}^+}{0.725\text{L solution}} = 0.03786\text{M } \text{Na}^+ \}\\

\[\text{c. } [\text{PO}_4^{3-}] = 1.26 \times 10^{-2}\text{M}\] \{0.009150mol Na$_3$PO$_4$ \(\frac{1\text{mol } \text{PO}_4^{3-}}{1\text{mol Na}_3\text{PO}_4} = 0.009150\text{mol } \text{PO}_4^{3-} ; [\text{PO}_4^{3-}] = \frac{0.009150\text{mol } \text{PO}_4^{3-}}{0.725\text{L solution}} = 0.01262\text{M } \text{PO}_4^{3-} \}

II. a. \([\text{AsO}_4^{3-}] = 0.50M\) \{0.50M (NH$_4$)$_3$AsO$_4$ \(\frac{1\text{mol AsO}_4^{3-}}{1\text{mol (NH}_4)_3\text{AsO}_4} = 0.50\text{M AsO}_4^{3-} \}\\

\[\text{b. } [\text{NH}_4^+] = 1.5M\] \{0.50M (NH$_4$)$_3$AsO$_4$ \(\frac{3\text{mol } \text{NH}_4^+}{1\text{mol (NH}_4)_3\text{AsO}_4} = 1.50\text{M } \text{NH}_4^+ \}

III. \(0.33g \text{ NaOH}\) \[\{M = \text{mol/L; mol} = M \times L = (0.15)(0.055) = 0.00825\text{mol NaOH} ;\\\]

\(0.00825\text{mol NaOH} \left(\frac{40.00\text{g NaOH}}{1\text{mol NaOH}}\right) = 0.330\text{g NaOH} \}

\[\text{II. } 0.0173\text{ g}\] \[\{M = \text{mol/L; mol} = M \times L = (3.16 \times 10^{-3}\text{M H}^+) (0.150\text{L}) = 0.000474\text{mol H}^+ ;\\\]

\(0.000474\text{mol H}^+ \left(\frac{1\text{mol HCl}}{1\text{mol H}^+}\right) = 0.00474\text{mol HCl} ; 0.000474\text{mol HCl} \left(\frac{36.45\text{g HCl}}{1\text{mol HCl}}\right) = 0.01728g \text{ HCl} \}

\[\text{III. } 9.29ml\] \[\{M = \text{mol/L; L = mol/M; find mol Ba(NO}_3)_2; 1.25g Ba(OH)_2 \left(\frac{1\text{mol Ba(OH)}_2}{261.32g \text{ Ba(OH)}_2}\right) = 0.004783\text{mol Ba(OH)}_2 ;\\\]

\(L = \frac{\text{mol}}{M} = \frac{0.004783\text{mol Ba(OH)}_2}{0.515M \text{ Ba(OH)}_2} = 0.009287L = 9.287\text{ml} \}

IV. \(90.0\text{ml of } 1.25\text{M Na}_2\text{S}\) \\{dilution: M$_1$V$_1$ = M$_2$V$_2$; (1.25M)(x mL) = (0.450M)(250mL); x = 90.0ml\}

\[\text{II. } 0.977L \text{ water}\] \{dilution: M$_1$V$_1$ = M$_2$V$_2$; (2.15M)(x L) = (0.750M)(1.5L); x = 0.523L;\\\]

\(x = \text{amount of } 2.15\text{M used} \neq \text{amount of water; } V_2 = \text{total volume} = V_1 + H_2O \text{ added}; 1.50L = 0.523L + H_2O; H_2O = 0.977L \}

\[\text{III. } 6.0 \times 10^2 \text{ ml}\] \{dilution: M$_1$V$_1$ = M$_2$V$_2$; (2.4M)(25mL) = (0.10M)(x mL); x = 600mL\}
5. I. 1.0 x 10^2 ml  {from the flow chart: this is a M_A \rightarrow M_B calculation;}

**Step 1:** mol_{HCl} = M_{HCl} \times L_{HCl} = (0.20 \text{M})(0.050 \text{L}) = 0.010 \text{mol HCl;}

**Step 2:** 0.010 \text{mol HCl} \left( \frac{1 \text{mol NaOH}}{1 \text{mol HCl}} \right) = 0.010 \text{mol NaOH;}

**Step 3:** \( L = \frac{\text{mol}}{M} = \frac{0.010 \text{mol NaOH}}{0.10 \text{M NaOH}} = 0.10L = 100 \text{ml} \); the stoichiometric ratio between an acid and base can be determined by inspection without writing the reaction; the ratio must be: 1 H^+ to 1 OH^- or in other words, the same number of H^+ and OH^-; since both HCl and NaOH have 1 H^+ and 1 OH^-, respectively, the ratio between HCl and NaOH must be 1:1

II. 22ml  {from the flow chart: this is a M_A \rightarrow M_B calculation;}

**Step 1:** mol_{Ba(OH)2} = M_{Ba(OH)2} \times L_{Ba(OH)2} = (0.50 \text{M})(0.050 \text{L}) = 0.025 \text{mol Ba(OH)2;}

**Step 2:** 0.025 \text{mol Ba(OH)2} \left( \frac{2 \text{mol H}_3\text{C}_6\text{H}_5\text{O}_7}{3 \text{mol Ba(OH)2}} \right) = 0.0167 \text{mol H}_3\text{C}_6\text{H}_5\text{O}_7; 

**Step 3:** \( L = \frac{\text{mol}}{M} = \frac{0.0167 \text{mol H}_3\text{C}_6\text{H}_5\text{O}_7}{0.75 \text{M H}_3\text{C}_6\text{H}_5\text{O}_7} = 0.0222L = 22.2 \text{ml H}_3\text{C}_6\text{H}_5\text{O}_7 \); the stoichiometric ratio between an acid and base can be determined by inspection without writing the reaction; the ratio must be: 1H^+ to 1OH^- or in other words, the same number of H^+ and OH^-; since Ba(OH)2 has 2 OH^- and H_3C_6H_5O_7 has 3 H^+ (triprotic = 3 H^+), the common factor for these 2 numbers is 6; so there needs to be 3 Ba(OH)2 (contains 6 OH^-) and 2 H_3C_6H_5O_7 (contains 6 H^+)
6. I. 0.152M {from the flow chart: this is a \( M_A \rightarrow M_B \) calculation;  
  **Step 1:** \( \text{mol}_\text{H}_{2}\text{SO}_4 = M_{\text{H}_{2}\text{SO}_4} \times L_{\text{H}_{2}\text{SO}_4} = \frac{0.100\text{M}}{} \times 0.0263\text{L} = 0.00263\text{mol H}_2\text{SO}_4; \)
  **Step 2:** \( 0.00263\text{mol H}_2\text{SO}_4 \times \left( \frac{2\text{mol NaOH}}{1\text{mol H}_2\text{SO}_4} \right) = 0.00526\text{mol NaOH}; \)
  **Step 3:** \( \frac{\text{mol}_{\text{NaOH}}}{L_{\text{NaOH}}} = \frac{0.00526\text{mol NaOH}}{0.0346\text{L}} = 0.1520\text{M NaOH}; \)  
  the stoichiometric ratio between an acid and base can be determined by inspection without writing the reaction; the ratio must be: \( 1\text{H}^+ \rightarrow 1\text{OH}^- \) or in other words, the same number of \( \text{H}^+ \) and \( \text{OH}^- \); since \( \text{H}_2\text{SO}_4 \) has 2 \( \text{H}^+ \) and \( \text{NaOH} \) has 1 \( \text{OH}^- \), the common factor for these 2 numbers is 2; so there needs to be 
  1 \( \text{H}_2\text{SO}_4 \) (contains 2 \( \text{H}^+ \)) and 2 \( \text{NaOH} \) (contains 2 \( \text{OH}^- \))

II. 0.100M {from the flow chart: this is a \( M_A \rightarrow M_B \) calculation;  
  **Step 1:** \( \text{mol}_\text{HCl} = M_{\text{HCl}} \times L_{\text{HCl}} = \frac{0.400\text{M}}{} \times 0.0125\text{L} = 0.00500\text{mol HCl}; \)
  **Step 2:** \( 0.00500\text{mol HCl} \times \left( \frac{1\text{mol Ca(OH)}_2}{2\text{mol HCl}} \right) = 0.00250\text{mol Ca(OH)}_2; \)
  **Step 3:** \( \frac{\text{mol}_{\text{Ca(OH)}_2}}{L_{\text{Ca(OH)}_2}} = \frac{0.00250\text{mol Ca(OH)}_2}{0.0250\text{L}} = 0.1000\text{M Ca(OH)}_2; \) the stoichiometric ratio between an acid and base can be determined by inspection without writing the reaction; the ratio must be: \( 1\text{H}^+ \rightarrow 1\text{OH}^- \) or in other words, the same number of \( \text{H}^+ \) and \( \text{OH}^- \); since \( \text{HCl} \) has 1 \( \text{H}^+ \) and \( \text{Ca(OH)}_2 \) has 2 \( \text{OH}^- \), the common factor for these 2 numbers is 2; so there needs to be 2 \( \text{HCl} \) (contains 2 \( \text{H}^+ \)) and 1 \( \text{Ca(OH)}_2 \) (contains 2 \( \text{OH}^- \))

III. 0.0600M {from the flow chart: this is a \( M_A \rightarrow M_B \) calc; let \( \text{H}_3\text{A} \) be a triprotic acid;  
  **Step 1:** \( \text{mol}_\text{H}_3\text{A} = M_{\text{H}_3\text{A}} \times L_{\text{H}_3\text{A}} = \frac{0.100\text{M}}{} \times 0.0200\text{L} = 0.00200\text{mol H}_3\text{A}; \)
  **Step 2:** \( 0.00200\text{mol H}_3\text{A} \times \left( \frac{3\text{mol Ba(OH)}_2}{2\text{mol H}_3\text{A}} \right) = 0.00300\text{mol Ba(OH)}_2; \)
  **Step 3:** \( \frac{\text{mol}_{\text{Ba(OH)}_2}}{L_{\text{Ba(OH)}_2}} = \frac{0.00300\text{mol Ba(OH)}_2}{0.0500\text{L}} = 0.0600\text{M Ba(OH)}_2; \) the stoichiometric ratio between an acid and base can be determined by inspection without writing the reaction; the ratio must be: \( 1\text{H}^+ \rightarrow 1\text{OH}^- \) or in other words, the same number of \( \text{H}^+ \) and \( \text{OH}^- \); since \( \text{H}_3\text{A} \) has 3 \( \text{H}^+ \) and \( \text{Ba(OH)}_2 \) has 2 \( \text{OH}^- \), the common factor for these two numbers is 6; so there needs to be 2 \( \text{H}_3\text{A} \) (contains 6 \( \text{H}^+ \)) and 3 \( \text{Ba(OH)}_2 \) (contains 6 \( \text{OH}^- \))

7. I. 11.4g \( \text{Na}_2\text{S} \) {this is a \( M_A \rightarrow g_B \) calc; 
  \( \text{mol}_{\text{Al(NO)}_3}_3 = M_{\text{Al(NO)}_3}_3 \times L_{\text{Al(NO)}_3}_3 = \frac{0.275\text{M}}{} \times 0.355\text{L} = 0.09763\text{mol Al(NO)}_3; \) 
  \( \left( \frac{3\text{mol Na}_2\text{S}}{2\text{mol Al(NO)}_3} \right) \left( \frac{78.04\text{g Na}_2\text{S}}{1\text{mol Na}_2\text{S}} \right) = 11.425\text{g Na}_2\text{S} \)}

II. 0.595L {this is a \( g_A \rightarrow M_B \) calculation; 
  \( \frac{0.500\text{g NaHCO}_3}{84.01\text{g NaHCO}_3} \left( \frac{1\text{mol NaHCO}_3}{1\text{mol NaHCO}_3} \right) \left( \frac{1\text{mol HCl}}{1\text{mol NaHCO}_3} \right) = 0.05952\text{mol HCl} \)}
8. a. \( \text{Pb(NO}_3\text{)}_2(aq) + 2\text{KI(aq)} \rightarrow \text{PbI}_2(s) + 2\text{KNO}_3(aq) \)

b. 0.313mol \( \text{PbI}_2 \) {this is a limiting reagent question since 2 reactant quantities were given; the calculation is: \( M_A \rightarrow M_B \) done twice; \( \text{Pb(NO}_3\text{)}_2; \text{mol Pb(NO}_3\text{)}_2 = M \times L = (1.25M)(0.450L) = 0.5625\text{mol Pb(NO}_3\text{)}_2; \)}

\[
\left(0.5625\text{mol Pb(NO}_3\text{)}_2\right) \left(\frac{1\text{mol PbI}_2}{1\text{mol Pb(NO}_3\text{)}_2}\right) = 0.5625\text{mol PbI}_2 ;
\]

\( \text{KI; mol KI = M x L = (2.50M)(0.250L) = 0.625mol KI; } \)

\[
\left(0.625\text{mol KI}\right) \left(\frac{1\text{mol PbI}_2}{2\text{mol KI}}\right) = 0.3125\text{mol PbI}_2 \}
\]

c. \( \text{KI produced the smaller amount of product so it is the limiting reagent} \)

d. 0.250mol \( \text{Pb(NO}_3\text{)}_2 \) \{left overs = starting amount - amount used; for amount used the calculation is: \( \text{LR} \rightarrow \text{EX} \); \}

\[
\left(0.625\text{mol KI}\right) \left(\frac{1\text{mol Pb(NO}_3\text{)}_2}{2\text{mol KI}}\right) = 0.3125\text{mol Pb(NO}_3\text{)}_2 \text{ used; left overs = 0.5625mol - 0.3125mol = 0.250mol Pb(NO}_3\text{)}_2 \}
\]

e. 0.357M \{[\text{Pb(NO}_3\text{)}_2] = \frac{0.250\text{mol Pb(NO}_3\text{)}_2}{(450\text{ml} + 250\text{ml})/1000} = 0.357M \}

f. \( \text{Pb}^{2+}, \text{NO}_3^- \), and \( \text{K}^+ \) \{\( \text{Pb(NO}_3\text{)}_2(aq), \text{PbI}_2(s), \text{and 2KNO}_3(aq) \) exist at the end of the reaction; ignore \( \text{PbI}_2(s) \) since it is a solid; the other two chemicals dissolve yielding: \( \text{Pb}^{2+}, \text{NO}_3^-, \text{and K}^+ \) \}

9. 80.8g/mol \{this is a \( M_A \rightarrow M_B \); molar mass = grams HA/mol HA; find mol LiOH from titration data:

\[
0.0569L \times 0.25M = 0.01423\text{mol LiOH; reaction: LiOH + HA} \rightarrow \text{H}_2\text{O + LiA;}
\]

\[
0.01423\text{mol LiOH} \left(\frac{1\text{mol HA}}{1\text{mol LiOH}}\right) = 0.01423\text{mol HA} ; \text{ molar mass} = \frac{\text{grams HA}}{\text{mol HA}} = \frac{1.15\text{g HA}}{0.01423\text{mol HA}} = 80.84g / \text{mol } \}
\]

10. a. -18,385kJ \{5.000mol \( \text{P}_4\text{S}_3\left(\frac{-3677kJ}{1\text{mol P}_4\text{S}_3}\right) = -18,385kJ \); can also be done as a proportionality:

\[
\frac{1\text{mol P}_4\text{S}_3}{-3677kJ} = \frac{5.000\text{mol P}_4\text{S}_3}{xkJ} ; \text{ cross multiply: } -18,385kJ = x \}
\]

b. -359.1kJ \{25.00g \( \text{O}_2 \left(\frac{1\text{mol O}_2}{32.00g \text{O}_2}\right) \left(\frac{-3677kJ}{8\text{mol O}_2}\right) = -359.1kJ \); can also be done as a proportionality:

\[
\frac{8\text{mol O}_2}{-3677kJ} = \frac{25.00g \text{O}_2}{xkJ} ; \text{ must be same units: } \frac{256g \text{O}_2}{-3677kJ} = \frac{25.00g \text{O}_2}{xkJ} ; \text{ cross multiply: } 256x = -91,925; x = -359.1kJ \}
\]

11. a. -4,088kJ \{10.0mol \( \text{O}_2 \left(\frac{-2044kJ}{5\text{mol O}_2}\right) = -4088kJ \); can also be done as a proportionality:

\[
\frac{5\text{mol O}_2}{-2044kJ} = \frac{10.0\text{mol O}_2}{xkJ} ; \text{ cross multiply: } -20440kJ = 5x; x = -4088kJ \}
\]

b. -1548kJ \{100.0g \( \text{CO}_2 \left(\frac{1\text{mol CO}_2}{44.01g \text{CO}_2}\right) \left(\frac{-2044kJ}{3\text{mol CO}_2}\right) = -1548kJ \); can also be done as a proportionality:

\[
\frac{3\text{mol CO}_2}{-2044kJ} = \frac{100.0g \text{CO}_2}{xkJ} ; \text{ must be same units: } \frac{132.03g \text{CO}_2}{-2044kJ} = \frac{100.0g \text{CO}_2}{xkJ} ; \text{ cross multiply: } 132.03x = -204400; x = -1548kJ \}
\]

12. Endothermic as it requires heat to boil water and endothermic means to absorb heat.