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 indicate the concentration of X⁺ in molarity

\[ M = \frac{\text{moles}_{\text{solute}}}{L_{\text{solution}}} \]

**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:** \( M = \frac{\text{mol}_{\text{solute}}}{L_{\text{solution}}} \) (How to ID problem: Contains 1 chemical and 1 concentration)

**Example 1:** How many grams NaCl are needed to prepare 450ml of a 0.15M NaCl solution?

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

\[ M = 0.15\text{mol/L}; L = 450\text{ml} \times (1\text{L}/1000\text{ml}) = 0.450\text{L}; \text{mol} = x; \]

\[ 0.15\text{mol}/\text{L} = x/0.450\text{L}; x = 0.0675\text{mol NaCl} \]

\[ (0.0675\text{mol NaCl}) \left( \frac{58.45\text{g NaCl}}{1\text{mol NaCl}} \right) = 3.945\text{g NaCl} = 3.9\text{g NaCl} \]

**Example 2:** What is the concentration of NH₄⁺ when 3.50 grams (NH₄)₂S are added to 750. ml of water?

**Answer 2:** 0.136M NH₄⁺ \{1 chemical and 1 concentration \( \rightarrow \) need to use \( M = \text{mol/L} \) but there will be an extra step for this problem;

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

\[ \text{mol NH}_4^+ = (3.50\text{g (NH}_4)_2\text{S}) \left( \frac{1\text{mol (NH}_4)_2\text{S}}{68.73\text{g (NH}_4)_2\text{S}} \right) \left( \frac{2\text{mol NH}_4^+}{1\text{mol (NH}_4)_2\text{S}} \right) = 0.1018\text{mol NH}_4^+ \]

\[ \frac{\text{L solution}}{750\text{ml} \times (1\text{L}/1000\text{ml})} = 0.750\text{L} \]

\[ [\text{NH}_4^+] = \frac{0.1018\text{mol NH}_4^+}{0.750\text{L solution}} = 0.1358 \text{M NH}_4^+ = 0.136\text{M NH}_4^+ \}

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

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

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; \( V_2 = V_1 + \text{water added} \)

**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 \{1 chemical and 2 concentrations \( \rightarrow \) a dilution; 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)

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

\[ (0.150\text{mol/L})(1250\text{ml}) = (12.0\text{mol/L})(x\text{ml}) \]

\( V_1 \text{ and } V_2 \) 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)

![Stoichiometric Molarity Problems flowchart](https://example.com/flowchart.png)
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 HCl; mol HCl = M x L = \( \frac{0.150M}{(27.5ml)(L/1000ml)} \) = 0.004125mol HCl

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

\[
0.004125\text{mol HCl} \left( \frac{1\text{mol Ba(OH)}_2}{2\text{mol HCl}} \right) = 0.0020625\text{mol Ba(OH)}_2
\]

[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⁻): 2HCl(aq) + Ba(OH)₂ → 2H₂O(l) + BaCl₂(aq)]

Step 3: calculate the concentration using M_Ba(OH)_2 = mol Ba(OH)_2/L Ba(OH)_2

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

ENERGY

HEAT:

heat released from the system – solution feels warm → exothermic

heat absorbed by the system – solution feels cool → endothermic

Units of heat = J (joules)

Scaling up or down the heat of a reaction

Example 5: How much heat is released when 16.0g O₂ reacts in the reaction below?

When this reaction occurs  \( 2\text{CuS} + 3\text{O}_2 \rightarrow 2\text{CuO} + 2\text{SO}_2 \)  193 kJ are released

Answer 5: -32.2kJ

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

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

can also be done as a proportionality: \( \frac{3\text{mol O}_2}{193\text{kJ released}} = \frac{16.0\text{g O}_2}{x} \) (a proportionality is: “3mol O₂ is to 193kJ released as 16g O₂ is to x”);

change to the same units (both in grams or both in moles): \( \frac{3\text{mol O}_2}{193\text{kJ released}} = \frac{0.500\text{mol O}_2}{x} \); cross multiply: \( 3x = 96.5\text{kJ}; x = -2.2\text{kJ released} \)

Example 6: When this reaction occurs, \( 3\text{Fe(s)} + 2\text{O}_2(g) \rightarrow 3\text{Fe}_3\text{O}_4(s) \), 266.7kJ are released. How many grams of Fe can form \( \text{Fe}_3\text{O}_4 \) when 19.9kJ of heat are released?

Answer 6:

scaling up: \( 19.9\text{kJ} \left( \frac{3\text{mol Fe}}{266.7\text{kJ}} \right) \left( \frac{55.85\text{g Fe}}{1\text{mol Fe}} \right) = 12.50\text{g Fe} \)

can also be done as a proportionality: \( \frac{3\text{mol Fe}}{266.7\text{kJ}} = \frac{x\text{mol Fe}}{19.9\text{kJ}} \); cross multiply: \( 266.7x = 59.7; x = 0.224\text{mol Fe}; 0.224\text{mol Fe} \left( \frac{55.85\text{g Fe}}{1\text{mol Fe}} \right) = 12.50\text{g Fe} \)

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 Na₃PO₄ when 1.50g of Na₃PO₄ is dissolved into a total volume of 725ml?  b. What is the Na⁺ concentration?  c. What is the PO₄³⁻ concentration?

2. I. If the concentration of Na₂SO₄ is 0.15M, what is the concentration of Na⁺?
II. If the concentration of (NH₄)₃AsO₄ is 0.50M, what is the concentration of AsO₄³⁻? What is the concentration of NH₄⁺?
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 \([H^+] = 3.16 \times 10^{-3} \text{ M}\)? 
III. How many milliliters of 0.515M Ba(NO\(_3\))\(_2\) solution will provide 1.25 grams 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\(_3\))\(_3\)? 
II. What volume of 0.100M HCl solution is required to react with 5.00g of NaHCO\(_3\) in the following reaction? 
HCl + NaHCO\(_3\) → H\(_2\)O + CO\(_2\) + NaCl

8. 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?

9. (This is a long and more challenging question.) a. 450.ml 1.25M Pb(NO\(_3\))\(_2\)(aq) solution was mixed with 250.ml 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?

**Intro to Energy**

10. Use the reaction shown to answer the following questions. 
    \[ P_4S_3(s) + 8O_2(g) \rightarrow P_4O_{10}(s) + 3SO_2(g) \] 
    3677kJ released when this reaction occurs 
    a. How much heat would be released if 5.000mol P\(_4\)S\(_3\)(s) were consumed? 
    b. How much heat would be released if 25.00g O\(_2\)(g) were consumed?

11. Use the reaction shown to answer the following questions. 
    \[ C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(g) \] 
    2044kJ released when this reaction occurs 
    a. How much heat would be released if 10.0mol O\(_2\)(g) were consumed? 
    b. How much heat would be released if 100.0g CO\(_2\)(g) were produced?
12. How many grams of H₂ can be formed when 250.0kJ are absorbed by the reaction shown below?

\[ \text{C}_2\text{H}_6(g) \rightarrow 2\text{C}(s) + 3\text{H}_2(g) \quad \text{84.7kJ/mol absorbed when this reaction occurs} \]

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

**ANSWERS**

1. I. \([\text{HCl}] = 0.192\text{M} \quad \{1.75\text{g HCl} \left( \frac{1\text{mol HCl}}{36.45\text{g HCl}} \right) = 0.04801\text{mol HCl} ; \quad [\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} \quad \{1.50\text{g Na}_3\text{PO}_4 \left( \frac{1\text{mol Na}_3\text{PO}_4}{163.94\text{g Na}_3\text{PO}_4} \right) = 0.00915\text{mol Na}_3\text{PO}_4 ; \quad [\text{Na}_3\text{PO}_4] = \frac{0.00915\text{mol Na}_3\text{PO}_4}{0.725\text{L solution}} = 0.01262\text{M Na}_3\text{PO}_4 \}

b. \([\text{Na}^+] = 3.79 \times 10^{-2}\text{M} \quad \{0.00915\text{mol Na}_3\text{PO}_4 \left( \frac{3\text{mol Na}^+}{1\text{mol Na}_3\text{PO}_4} \right) = 0.02745\text{mol Na}^+ ; \quad [\text{Na}^+] = \frac{0.02745\text{mol Na}^+}{0.725\text{L solution}} = 0.03786\text{M Na}^+ \}

c. \([\text{PO}_4^{3-}] = 1.26 \times 10^{-2}\text{M} \quad \{0.00915\text{mol Na}_3\text{PO}_4 \left( \frac{1\text{mol PO}_4^{3-}}{1\text{mol Na}_3\text{PO}_4} \right) = 0.00915\text{mol PO}_4^{3-} ; \quad [\text{PO}_4^{3-}] = \frac{0.00915\text{mol PO}_4^{3-}}{0.725\text{L solution}} = 0.01262\text{M PO}_4^{3-} \}

2. I. \([\text{Na}^+] = 0.30\text{M} \quad \{0.15\text{M Na}_2\text{SO}_4 \left( \frac{2\text{mol Na}^+}{1\text{mol Na}_2\text{SO}_4} \right) = 0.30\text{M Na}^+ \}

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

\}[\text{NH}_4^+] = 1.5\text{M} \quad \{0.50\text{M (NH}_4\text{)}_3\text{AsO}_4 \left( \frac{3\text{mol NH}_4^+}{1\text{mol (NH}_4\text{)}_3\text{AsO}_4} \right) = 1.5\text{M NH}_4^+ \}

3. I. \(0.33\text{g NaOH} \quad \{M = \text{mol/L}; \quad \text{mol} = M \times L = (0.15)(0.055) = 0.00825\text{mol NaOH}; \quad 0.00825\text{mol NaOH} \left( \frac{40.00\text{g NaOH}}{1\text{mol NaOH}} \right) = 0.330\text{g NaOH} \}

II. \(0.0173\text{g} \quad \{M = \text{mol/L}; \quad \text{mol} = M \times L = (3.16 \times 10^{-3}\text{M H}^+) (0.150\text{L}) = 0.000474\text{mol H}^+; \quad 0.000474\text{mol H}^+ \left( \frac{1\text{mol HCl}}{1\text{mol H}^+} \right) = 0.00474\text{mol HCl}; \quad 0.000474\text{mol HCl} \left( \frac{36.45\text{g HCl}}{1\text{mol HCl}} \right) = 0.01728\text{g HCl} \}

III. \(9.29\text{ml} \quad \{M = \text{mol/L}; \quad L = \text{mol/M}; \quad \text{find mol Ba(NO}_3\text{)}_2; \quad 1.25\text{g Ba(OH)}_2 \left( \frac{1\text{mol Ba(OH)}_2}{261.32\text{g Ba(OH)}_2} \right) = 0.004783\text{mol Ba(OH)}_2; \quad L = \frac{\text{mol}}{M} = \frac{0.004783\text{mol Ba(OH)}_2}{0.515\text{M Ba(OH)}_2} = 0.009287\text{L} = 9.287\text{ml} \}

4. I. \(90.0\text{ml of 1.25M Na}_2\text{S} \quad \{\text{dilution: } M_1 V_1 = M_2 V_2; \quad (1.25\text{M})(x \text{ ml}) = (0.450\text{M})(250\text{ml}); \quad x = 90.0\text{ml} \}

II. \(0.977\text{L water} \quad \{\text{dilution: } M_1 V_1 = M_2 V_2; \quad (2.15\text{M})(x \text{ L}) = (0.750\text{M})(1.5\text{L}); \quad x = 0.523\text{L}; \quad \text{water} = \text{amount of 2.15M used} = \text{amount of water}; \quad V_2 = \text{total volume} = V_1 + \text{H}_2\text{O added}; \quad 1.50\text{L} = 0.523\text{L} + \text{H}_2\text{O}; \quad \text{H}_2\text{O} = 0.977\text{L} \}

III. \(6.0 \times 10^2\text{ ml} \quad \{\text{dilution: } M_1 V_1 = M_2 V_2; \quad (2.4\text{M})(25\text{ml}) = (0.10\text{M})(x \text{ ml}); \quad x = 600\text{ml} \} \)
5. I. 1.0 x 10^{-2} \text{ ml} \quad \text{(from the flow chart: this is a } M_A \rightarrow M_B \text{ calculation;)}

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

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

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

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

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

\text{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 ;

\text{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 ; \text{ the stoichiometric ratio between an acid and base can be determined by inspection without writing the reaction; the ratio must be: } 1\text{H}^+ \text{ to } 1\text{OH}^- \text{ or in other words, the same number of H}^+ \text{ and OH}^-; \text{ since Ba(OH)2 has } 2 \text{OH}^- \text{ and H}_3\text{C}_6\text{H}_5\text{O}_7 \text{ has } 3 \text{H}^+ \text{ (triprotic = } 3 \text{H}^+ \text{), the common factor for these 2 numbers is 6; so there needs to be 3 Ba(OH)2 (contains 6 OH^-) and 2 H}_3\text{C}_6\text{H}_5\text{O}_7 \text{ (contains } 6 \text{H}^+\))
6. 0.152M \{\text{from the flow chart: this is a } M_A \rightarrow M_B \text{ calculation;}
\]
\begin{align*}
\text{Step 1: } & \text{mol}_{H_2SO_4} = M_{H_2SO_4} \times L_{H_2SO_4} = (0.100M)(0.0263L) = 0.00263\text{mol } H_2SO_4; \\
\text{Step 2: } & 0.00263\text{mol } H_2SO_4 \left( \frac{2\text{mol } NaOH}{1\text{mol } H_2SO_4} \right) = 0.00526\text{mol } NaOH; \\
\text{Step 3: } & M_{NaOH} = \frac{\text{mol}_{NaOH}}{L_{NaOH}} = \frac{0.00526\text{mol } NaOH}{0.0346L} = 0.1520\text{M } NaOH; \\
\end{align*}

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 H\(_2\)SO\(_4\) has 2 H\(^+\) and NaOH has 1 OH\(^-\), the common factor for these 2 numbers is 2; so there needs to be 1 H\(_2\)SO\(_4\) (contains 2 H\(^+\)) and 2 NaOH (contains 2 OH\(^-\))

II. 0.100M \{\text{from the flow chart: this is a } M_A \rightarrow M_B \text{ calculation;}
\]
\begin{align*}
\text{Step 1: } & \text{mol}_{HCl} = M_{HCl} \times L_{HCl} = (0.400M)(0.0125L) = 0.00500\text{mol } HCl; \\
\text{Step 2: } & 0.00500\text{mol } HCl \left( \frac{1\text{mol } Ca(OH)\text{)}_{2}}{2\text{mol } HCl} \right) = 0.00250\text{mol } Ca(OH)\text{)}_{2}; \\
\text{Step 3: } & M_{Ca(OH)\text{)}_{2}} = \frac{\text{mol}_{Ca(OH)\text{)}_{2}}}{L_{Ca(OH)\text{)}_{2}}} = \frac{0.00250\text{mol } Ca(OH)\text{)}_{2}}{0.0250L} = 0.1000\text{M } Ca(OH)\text{)}_{2}; \text{ 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 HCl has 1 H\(^+\) and Ca(OH)\(_2\) has 2 OH\(^-\), the common factor for these 2 numbers is 2; so there needs to be 2 HCl (contains 2 H\(^+\)) and 1 Ca(OH)\(_2\) (contains 2 OH\(^-\))
\end{align*}

III. 0.0600M \{\text{from the flow chart: this is a } M_A \rightarrow M_B \text{ calculation; let H}_3\text{A be a triprotic acid;}
\]
\begin{align*}
\text{Step 1: } & \text{mol}_{H_3A} = M_{H_3A} \times L_{H_3A} = (0.100M)(0.0200L) = 0.00200\text{mol } H_3A; \\
\text{Step 2: } & 0.00200\text{mol } H_3A \left( \frac{3\text{mol } Ba(OH)\text{)}_{2}}{2\text{mol } H_3A} \right) = 0.00300\text{mol } Ba(OH)\text{)}_{2}; \\
\text{Step 3: } & M_{Ba(OH)\text{)}_{2}} = \frac{\text{mol}_{Ba(OH)\text{)}_{2}}}{L_{Ba(OH)\text{)}_{2}}} = \frac{0.00300\text{mol } Ba(OH)\text{)}_{2}}{0.0500L} = 0.0600\text{M } Ba(OH)\text{)}_{2}; \text{ 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 H}_3\text{A has 3 H}^+ and Ba(OH)\(_2\) has 2 OH\(^-\), the common factor for these two numbers is 6; so there needs to be 2 H}_3\text{A (contains 6 H}\(^+\)) and 3 Ba(OH)\(_2\) (contains 6 OH\(^-\))
\end{align*}

7. I. 11.4g Na\(_2\)S \{\text{this is a } M_A \rightarrow g_B \text{ calculation;}
\]
\begin{align*}
\text{mol}_{Al(NO)\text{)}_{3}} = & M_{Al(NO)\text{)}_{3} \times L_{Al(NO)\text{)}_{3} = (0.275M)(0.355L) = 0.09763\text{mol } Al(NO)\text{)}_{3}; \\
\left( 0.09763\text{mol } Al(NO)\text{)}_{3} \right) \left( \frac{3\text{mol } Na_2S}{2\text{mol } Al(NO)\text{)}_{3}} \right) \left( \frac{78.04g Na_2S}{1\text{mol } Na_2S} \right) = 11.425g Na_2S \}
\end{align*}

II. 0.595L \{\text{this is a } g_A \rightarrow M_B \text{ calculation; \left( 5.00g NaHCO}_3 \right) \left( \frac{\text{lmol NaHCO}_3}{84.01g NaHCO}_3 \right) \left( \frac{\text{lmol HCl}}{\text{lmol NaHCO}_3} \right) = 0.05952\text{mol } HCl
\]
\begin{align*}
L_{HCl} = \frac{\text{mol}_{HCl}}{M_{HCl}} = \frac{0.05952\text{mol}}{0.100M} = 0.5952\text{L } HCl \}
\end{align*}
8. 80.8 g/mol (this is a M → mol B; molar mass = grams HA/mol HA; find mol LiOH from titration data: 0.0569 L x 0.25 M = 0.01423 mol LiOH; reaction: LiOH + HA → H₂O + LiA; 0.01423 mol LiOH (1 mol HA / 1 mol LiOH) = 0.01423 mol HA; molar mass = grams HA/mol HA = 1.15 g HA / 0.01423 mol HA = 80.84 g/mol)

9. a. Pb(NO₃)₂(aq) + 2KI(aq) → PbI₂(s) + 2KNO₃(aq)
b. 0.313 mol PbI₂ (this is a limiting reagent question since 2 reactant quantities were given; the calculation is: Mₐ → mol B done twice; Pb(NO₃)₂; mol Pb(NO₃)₂ = M x L = (1.25 M)(0.450 L) = 0.5625 mol Pb(NO₃)₂; (0.5625 mol Pb(NO₃)₂)(1 mol PbI₂ / 1 mol Pb(NO₃)₂) = 0.5625 mol PbI₂;
   KI; mol KI = M x L = (2.50 M)(0.250 L) = 0.625 mol KI; (0.625 mol KI)(1 mol PbI₂ / 2 mol KI) = 0.3125 mol PbI₂)

c. KI (KI produced the smaller amount of product so it is the limiting reagent)
d. 0.250 mol Pb(NO₃)₂ (leavings = starting amount – amount used; for amount used the calculation is: LR → EX; (0.625 mol KI)(1 mol Pb(NO₃)₂ / 2 mol KI) = 0.3125 mol Pb(NO₃)₂ used; leavings = 0.5625 mol – 0.3125 mol = 0.250 mol Pb(NO₃)₂)

e. 0.357 M (mol Pb(NO₃)₂ = L / Lₜₒₜ₉ = 0.250 mol Pb(NO₃)₂ / (450 ml + 250 ml)/1000 = 0.357 M)
f. Pb⁺², NO₃⁻, and K⁺ (Pb(NO₃)₂(aq), PbI₂(s), and 2KNO₃(aq) exist at the end of the reaction; ignore PbI₂(s) since it is a solid; the other two chemicals dissolve yielding: Pb⁺², NO₃⁻, and K⁺)

10. a. 18,385 kJ released (5.000 mol P₄S₃(3677 kJ released / 1 mol P₄S₃) = 18,385 kJ released; can also be done as a proportionality: 1 mol P₄S₃ / 3677 kJ released = 5.000 mol P₄S₃ / x kJ; cross multiply: x = 18,385 kJ released)
b. 359.1 kJ released (25.00 g O₂(3677 kJ released / 32.00 g O₂) = 359.1 kJ released; can also be done as a proportionality: 8 mol O₂ / 3677 kJ released = 25.00 g O₂ / x kJ; must be same units: 256 x = 25.00 g O₂ / 3677 kJ released; cross multiply: 256x = 91,925; x = 359.1 kJ)

11. a. 4,088 kJ released (10.0 mol O₂(2044 kJ released / 5 mol O₂) = 4088 kJ released; can also be done as a proportionality: 5 mol O₂ / 2044 kJ released = 10.0 mol O₂ / x kJ; cross multiply: 5x = 20440 kJ; x = 4088 kJ released)
b. -1548 kJ (100.0 g CO₂(2044 kJ released / 3 mol CO₂) = 1548 kJ released; can also be done as a proportionality: 3 mol CO₂ / 2044 kJ released = 100.0 g CO₂ / x kJ; must be same units: 132.03 g CO₂ / 2044 kJ released = 100.0 g CO₂ / x kJ; cross multiply: 132.03x = 204400; x = 1548 kJ released)

12. 17.9 g H₂ (scaling up: 250.0 kJ(3 mol H₂ / 84.7 kJ) = 2.02 g H₂; can also be done as a proportionality: 3 mol H₂ / 84.7 kJ = x mol H₂ / 250.0 kJ; cross multiply: 84.7x = 750.0; x = 8.855 mol H₂; 8.855 mol H₂ (2.02 g H₂ / 1 mol H₂) = 17.89 g H₂)

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