Writing and Balancing Equations for Chemical Reactions

1. (12 points) Balance the following equations:
   a) The reaction of aluminum with iron(III) oxide
      \[ \textcolor{red}{\underline{\text{Fe}_2\text{O}_3}}(s) + \textcolor{blue}{\underline{\text{Al}}}(s) \rightarrow \textcolor{green}{\underline{\text{Fe}}}(s) + \textcolor{purple}{\underline{\text{Al}_2\text{O}_3}}(s) \]
   b) The reaction of aluminum trichloride with water
      \[ \textcolor{red}{\underline{\text{AlCl}_3}}(g) + \textcolor{blue}{\underline{\text{H}_2\text{O}}}(\text{liq}) \rightarrow \textcolor{green}{\underline{\text{HCl}}}(g) + \textcolor{purple}{\underline{\text{Al}_2\text{O}_3}}(s) \]
   c) The reaction of magnesium with carbon dioxide gives elemental carbon and magnesium oxide.

2. (8 points) Complete and balance the following reactions.
   (a) \[ \textcolor{red}{\underline{\text{NaOH}}}(\text{aq}) + \textcolor{blue}{\underline{\text{HNO}_3}}(\text{aq}) \rightarrow \textcolor{green}{\underline{\text{H}_2\text{O}}}(\ell) \]
   (b) \[ \textcolor{red}{\underline{\text{AlCl}_3}}(\text{aq}) + \textcolor{blue}{\underline{\text{NaOH}}}(\text{aq}) \rightarrow \textcolor{green}{\underline{\text{NaCl}}} \]

3. (5 points) Identify each of the following reactions as an acid-base reaction, precipitation reaction, or gas-forming reaction.

<table>
<thead>
<tr>
<th>Reaction Type</th>
<th>Reaction</th>
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<tbody>
<tr>
<td>Acid-base</td>
<td>(\text{Ba(OH)}_2(s) + \text{HNO}_3(\text{aq}) \rightarrow \text{Ba(NO}_3)_2 + \text{H}_2\text{O}(\ell))</td>
</tr>
<tr>
<td>Precipitation</td>
<td>(\text{BaCl}_2 + \text{Na}_2\text{CO}_3 \rightarrow \text{BaCO}_3 + \text{NaCl})</td>
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<tr>
<td>Gas-forming</td>
<td>(\text{Mg(OH)}_2(s) + 2 \text{HNO}_3(\text{aq}) \rightarrow )</td>
</tr>
<tr>
<td>Precipitation</td>
<td>(\text{SrCO}_3(s) + 2 \text{HCl}(\text{aq}) \rightarrow )</td>
</tr>
<tr>
<td>Gas-forming</td>
<td>(\text{Pb(NO}_3)_2(\text{aq}) + 2 \text{NaOH}(\text{aq}) \rightarrow )</td>
</tr>
</tbody>
</table>

Molecular Composition

4. (4 points) Formulas
   (a) Which compound has the greatest percent by weight of carbon: \(\text{CH}_4\), \(\text{C}_2\text{H}_6\), or \(\text{C}_5\text{H}_{12}\)?
   \[ \text{Not a one of these!} \]
   (b) Naphthalene has the molecular formula \(\text{C}_{10}\text{H}_8\). Its empirical formula is \[ \underline{\text{C}_2\text{H}_6} \]

5. (3 points) Cyclohexylbenzene, has the empirical formula \(\text{C}_3\text{H}_4\). It molar mass is 160.3. Its molecular formula is
   (a) \(\text{C}_3\text{H}_4\) \hspace{1cm} (d) \(\text{C}_{12}\text{H}_{16}\)
   (b) \(\text{C}_6\text{H}_8\) \hspace{1cm} (e) \(\text{C}_{15}\text{H}_{20}\)
   (c) \(\text{C}_9\text{H}_{12}\) \hspace{1cm} (f) Not a one of these!
6. (3 points) Boron forms an extensive series of hydrides. If you isolate a new hydride that is 88.45% B, a possible molecular formula of the compound is

(a) $B_2H_6$  
(b) $B_3H_9$  
(c) $B_4H_{10}$  
(d) $B_{10}H_{14}$

7. (6 points) Controlled oxidation of 0.148 g of phosphorus in oxygen produces 0.263 g of a phosphorus oxide, $P_xO_y$.

How many moles of $O_2$ are used in the reaction?

(a) 0.00478 mol $O_2$  
(b) 0.00718 mol $O_2$  
(c) 0.00359 mol $O_2$  
(d) 0.00828 mol $O_2$

What is the empirical formula of the oxide?

(a) PO  
(b) PO$_2$  
(c) PO$_4$  
(d) P$_2$O$_3$  
(e) P$_2$O$_5$

8. (3 points) Transition metals can combine with carbon monoxide (CO) to form compounds such as Fe(CO)$_5$ and Co$_2$(CO)$_8$. Assume that you combine 0.125 g of nickel with CO and isolate 0.364 g of Ni(CO)$_x$. What is the value of $x$?

(a) 1  
(b) 2  
(c) 3  
(d) 4  
(e) 5

Stoichiometry

9. (10 points) The hydrocarbon benzene, C$_6$H$_6$, burns in air to give carbon dioxide and water.

$$2 \text{C}_6\text{H}_6(\text{liq}) + 15 \text{O}_2(\text{g}) \rightarrow 12 \text{CO}_2(\text{g}) + 6 \text{H}_2\text{O}(\text{g})$$

(a) If you burn 0.75 moles of benzene, _________ moles of carbon dioxide and _________ moles of water are produced and _________ moles of $O_2$ are used.

(b) If you obtain 15.0 g of water from the reaction, but should have obtained 18.0 g, the percent yield of water is ____________

(c) If you begin with 3.0 mol of benzene and 25 mol of $O_2$, this means the limiting reagent must be _______________
10. (6 points) When aluminum metal reacts with liquid bromine, the reaction produces aluminum tribromide.

\[ 2 \text{Al}(s) + 3 \text{Br}_2(\ell) \rightarrow 2 \text{AlBr}_3(s) \]

If you begin with 2.56 g of Al, how many grams of bromine (M = 159.8 g/mol) are required for complete reaction?

(a) 3.84 g
(b) 10.1 g
(c) 15.1 g
(d) 22.7 g

How many grams of aluminum tribromide (AlBr$_3$, M = 266.7 g/mol) will be produced from 2.56 g of Al and unlimited Br$_2$?

(a) 17.7 g
(b) 20.1 g
(c) 25.3 g
(d) 50.6 g

11. (3 points) A mixture of CuSO$_4$ (M = 159.61 g/mol) and CuSO$_4$$\cdot$5H$_2$O (M = 249.69 g/mol) has a mass of 1.245 g. After heating to drive off all the water, the mass of the mixture is 0.832 g. What was the weight percent of CuSO$_4$$\cdot$5H$_2$O in the original mixture?

(a) 91.6%
(b) 66.8%
(c) 63.9%
(d) 21.8%
(e) none of the above?

12. (3 points) Aspirin (M = 180.16 g/mol) is produced by the reaction of salicylic acid (M = 138.1 g/mol) and acetic anhydride (M = 102.1 g/mol).

\[ 2 \text{C}_7\text{H}_6\text{O}_3(s) + \text{C}_4\text{H}_6\text{O}_3(\ell) \rightarrow 2 \text{C}_9\text{H}_8\text{O}_4(s) + \text{H}_2\text{O}(\ell) \]

salicylic acid acetic anhydride aspirin

If you mix 100. g of each of the reactants, how many grams of aspirin can theoretically be obtained?

(a) 65.2 g aspirin
(b) 130. g aspirin
(d) 236 g aspirin
13. (15 points) The compound below is commonly called “dioxin” (see also the front cover). It is considered a particularly toxic substance.

(a) The molecular formula of the compound is ______________________ and its empirical formula is______________. Its molar mass (to three significant figures) is ______________.

(b) What is the weight percent of chlorine in the molecule? (Show your work)

(c) If you have 0.0128 g of dioxin, how many moles of the compound are present? (Show your work)

(d) How many molecules of dioxin are there in 0.0128 g of dioxin? (Show your work)

(e) How many Cl atoms are there in 0.0128 g of dioxin? (Show your work)
14. (10 points) One way to discover the stoichiometry of a reaction is add varying amounts of one reactant to a fixed amount of another. Suppose you carry out a series of experiments in which you add different amounts of zinc to a fixed mass of iodine. The results are plotted as mass of product versus mass of zinc.

(a) What mass of iodine is used when 2.50 g of Zn is consumed in the reaction? ________________

(b) What is the mole ratio of I\textsubscript{2} to Zn?
   i) 1 mol I\textsubscript{2} / 1 mol Zn
   ii) 2 mol I\textsubscript{2} / 1 mol Zn
   iii) 1 mol I\textsubscript{2} / 2 mol Zn
   iv) 3 mol I\textsubscript{2} / 2 mol Zn

(c) What is the empirical formula of the product of the reaction?
   i) ZnI
   ii) ZnI\textsubscript{2}
   iii) Zn\textsubscript{2}I
   iv) Zn\textsubscript{2}I\textsubscript{3}

(d) When 3 g of Zn are used, which is the limiting reactant, Zn or I\textsubscript{2}? ________________
Nature of Compounds in Aqueous Solution

1. (3 points) In each pair of compounds, identify the one that is soluble in water.
   (a) FeO or FeCl₂
   (b) barium chloride or barium sulfate
   (c) sodium sulfide or lead sulfide

2. (6 points) Writing Net Ionic Equations. A reaction you will do in the laboratory is
   $$\text{CuSO}_4 + \text{NH}_3 + \text{H}_2\text{O} \rightarrow \text{Cu(OH)}_2 + (\text{NH}_4)_2\text{SO}_4$$
   (Note: the equation above is not balanced)

   Which compound or compounds in the reaction is/are water soluble (not counting water)?

   _________________________________

   Which compound or compounds is/are NOT water soluble?

   _________________________________

   Write the balanced net ionic equation for the reaction.