CHEMICAL EQUATIONS AND STOICHIOMETRY

1. (7 points) Balance equations for the following reactions:
   
   (a) The combustion of octane
   $$ \text{C}_8\text{H}_{18}(l) + \text{O}_2(g) \rightarrow \text{CO}_2(g) + \text{H}_2\text{O}(l) $$

   (b) Explosive decomposition of ammonium nitrate
   $$ \text{NH}_4\text{NO}_3(s) \rightarrow \text{N}_2\text{O}(g) + \text{H}_2\text{O}(g) $$

2. (8 points) The very stable compound SF\textsubscript{6} is made by burning sulfur in an atmosphere of fluorine. The balanced equation is
   $$ \text{S}_8(s) + 24 \text{F}_2(g) \rightarrow 8 \text{SF}_6(g) $$

   (a) If you wish to prepare 2.50 moles of SF\textsubscript{6}, ____________ moles of S\textsubscript{8} and ____________ moles of F\textsubscript{2} are required.

   (b) If you actually obtain 16.0 g of SF\textsubscript{6}, but should have obtained 48.0 g of SF\textsubscript{6}, the percent yield of the product is _________________.

   (c) If you begin with 1.6 moles of sulfur, S\textsubscript{8}, and 35 moles of F\textsubscript{2}, this means ______________ is the limiting reagent.

3. (6 points) When aluminum metal reacts with liquid bromine, the reaction produces aluminum tribromide.
   $$ 2 \text{Al}(s) + 3 \text{Br}_2(l) \rightarrow 2 \text{AlBr}_3(s) $$

   (a) If you begin with 2.56 g of Al, what mass of Br\textsubscript{2} (M = 159.8 g/mol) is required for complete reaction?

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

   (b) What mass of aluminum tribromide (AlBr\textsubscript{3}, M = 266.7 g/mol) can be produced from 2.56 g of Al and unlimited Br\textsubscript{2}?

      (a) 17.7 g
      (b) 20.1 g
      (c) 25.3 g
      (d) 50.6 g
1. (8 points) Names, formulas, and water-solubility of compounds.

<table>
<thead>
<tr>
<th>Compound</th>
<th>Formula</th>
<th>Soluble</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonium chloride</td>
<td>NH₄Cl</td>
<td>Yes</td>
</tr>
<tr>
<td>Na₂SO₄</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cu₃(PO₄)₂</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Iron(III) hydroxide</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Copper(II) bromide</td>
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</tr>
</tbody>
</table>

2. (6 points) Each compound listed below is soluble in water. Provide the name, formula, and formulas of the constituent ions, as required.

<table>
<thead>
<tr>
<th>Compound</th>
<th>Name</th>
<th>Formula</th>
<th>Constituent Ions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonium chloride</td>
<td>NH₄Cl</td>
<td>NH₄⁺</td>
<td>Cl⁻</td>
</tr>
<tr>
<td>Magnesium bromide</td>
<td>NaCH₃CO₂</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1. (3 points) Give the oxidation number of each of the underlined atoms:

(a) AlCl₃

(b) HPO₄²⁻

(c) HNO₂

2. (8 points) Copper metal reacts readily with nitric acid to according to the balanced, net ionic equation

\[ \text{Cu(s)} + 4 \text{H}^+(aq) + 2 \text{NO}_3^-(aq) \rightarrow \text{Cu}^{2+}(aq) + \text{NO}_2(g) + 2 \text{H}_2\text{O(l)} \]

(a) The oxidation number of N in NO₃⁻ is ____________

(b) The substance oxidized is ________________ and the substance reduced is ________________

(c) The reducing agent is ________________
1. (11 points) Making Solutions
   (a) What mass of Na₂CO₃ (M = 106 g/mol) must be used to make 250. mL of a 0.10 M solution of sodium carbonate?
      (i) 1.06 g
      (ii) 2.65 g
      (iii) 10.6 g
      (iv) 26.5 g
   (b) What is the concentration of Cl⁻ ions in a 0.015 M solution of MgCl₂? [Cl⁻] = _____ M
   (c) In the laboratory you added water to 6.0 mL of 0.16 M CuSO₄. If the final volume of the diluted solution is 10.0 mL, what is the concentration of copper(II) ion in the diluted solution?
      (i) 0.064 M
      (ii) 0.080 M
      (iii) 0.096 M
      (iv) 0.27 M
   (d) What volume of 2.06 M KMnO₄ (M = 158.0 g/mol) contains 122 g of the solute?
      (i) 100 mL
      (ii) 122 mL
      (iii) 375 mL
      (iv) 772 mL

2. (3 points) What volume of 0.054 M H₂SO₄ is required to react completely with 1.56 g of KOH (M = 56.1 g/mol)?
   H₂SO₄(aq) + 2 KOH(aq) → 2 H₂O(l) + K₂SO₄(aq)
   (a) 129 mL
   (b) 258 mL
   (c) 516 mL
   (d) 750 mL
3. (3 points) The following reaction can be used to prepare iodine in the laboratory (see page 234)

\[ 2 \text{NaI(s)} + \text{MnO}_2(s) + 2 \text{H}_2\text{SO}_4(aq) \rightarrow \text{Na}_2\text{SO}_4(aq) + \text{MnSO}_4(aq) + \text{I}_2(g) + 2 \text{H}_2\text{O(l)} \]

What quantity of iodine, \( \text{I}_2 \) \((M = 253.8 \text{ g/mol})\), can be obtained if 20.0 g of \( \text{NaI} \) \((M = 149.9 \text{ g/mol})\) is mixed with 10.0 g of \( \text{MnO}_2 \) \((M = 86.9 \text{ g/mol})\) (and a stoichiometric excess of sulfuric acid).

(a) 16.9 g \( \text{I}_2 \)
(b) 33.8 g \( \text{I}_2 \)
(c) 29.2 g \( \text{I}_2 \)
(d) 58.4 g \( \text{I}_2 \)
(e) none of the above

4. (7 points) A compound has been isolated that can have either of two possible formulas:

(a) \( \text{K}[\text{Fe(C}_2\text{O}_4)_2(\text{H}_2\text{O})_2] \) \((M = 307.02 \text{ g/mol})\)
(b) \( \text{K}_3[\text{Fe(C}_2\text{O}_4)_3] \) \((M = 437.20 \text{ g/mol})\)

To find which is correct, you dissolve a weighed sample of the compound in acid and then titrate the oxalate ion \( (\text{C}_2\text{O}_4^{2-}) \) that comes from the compound with potassium permanganate, \( \text{KMnO}_4 \) (the source of the \( \text{MnO}_4^- \) ion). The balanced, net ionic equation for the titration is

\[ 5 \text{C}_2\text{O}_4^{2-}(aq) + 2 \text{MnO}_4^-(aq) + 16 \text{H}^+(aq) \rightarrow 2 \text{Mn}^{2+}(aq) + 10 \text{CO}_2(g) + 8 \text{H}_2\text{O(l)} \]

Titration of 1.356 g of the compound requires 34.50 mL of 0.108 M \( \text{KMnO}_4 \). Which is the correct formula of the iron-containing compound: a or b?
1. (14 points) Writing equations
   (a) Complete and balance the equation for the exchange reaction involving copper(II) sulfate and sodium hydroxide.
   
   \[ \underline{\quad} \text{CuSO}_4 + \underline{\quad} \text{NaOH} \rightarrow \]

   Is this reaction an acid-base reaction, precipitation reaction, or gas-forming reaction?

   (b) Complete and balance the equation for the exchange reaction involving copper(II) carbonate and nitric acid.
   
   \[ \underline{\quad} \text{CuCO}_3 + \underline{\quad} \text{HNO}_3 \rightarrow \]

   Is this reaction an acid-base reaction, precipitation reaction, or gas-forming reaction?

   (c) The balanced equation for a reaction you may do in the laboratory is
   
   \[ \text{AlCl}_3 + 3 \text{NaOH} \rightarrow 3 \text{NaCl} + \text{Al(OH)}_3 \]

   Which compounds in this reaction above are water soluble? ______________________________

   Which compounds are NOT water soluble? ____________________________________________

   Write the balanced, net ionic equation for the reaction.

2. (4 points) You want to prepare barium chloride, BaCl$_2$, using an exchange reaction of some type. To do this, you have the following reagents from which to select:

<table>
<thead>
<tr>
<th>BaSO$_4$</th>
<th>BaBr$_2$</th>
<th>BaCO$_3$</th>
<th>Ba(OH)$_2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>HCl</td>
<td>MgSO$_4$</td>
<td>AgNO$_3$</td>
<td>HNO$_3$</td>
</tr>
</tbody>
</table>

   Write a complete, balanced equation to show how you could prepare barium chloride using some combination of the reagents above. (Note: there are several possibilities.)

   What type of reaction did you choose (acid-base, precipitation, gas-forming)? ________________
Note: Specific heat capacity values are found in Table 6.1 in *Chemistry & Chemical Reactivity*.

1. Heat energy is transferred into water with a mass of 15.5 g, and the temperature of the water increases from 20.0 °C to 32.8 °C. What quantity of heat energy must have been transferred?
   (a) 830 J
   (b) 8.30 kJ
   (c) 15.5 kJ
   (d) 12.8 J
   (e) None of the above

2. Which requires more heat to warm from 22 °C to 85 °C?
   (a) 80.0 g of ethylene glycol.
   (b) 50.0 g of water

3. Suppose 25.0 g of methanol (CH₃OH) is warmed from 0.0 °C to its boiling point (64.6 °C). It is then vaporized. The specific heat capacity of methanol is 2.53 J/g*K, and its heat of vaporization is 1100 J/g. Which step of the process requires more heat?
   (a) Warming the liquid from 0.0 °C to 64.6 °C.
   (b) Vaporizing the liquid at 64.6 °C.

4. What is the temperature of the system if 3500 J of heat energy is added to 10.0 g of ice?
   (a) 0.0 °C
   (b) 3.9 °C
   (c) 16.0 °C
   (d) 27.5 °C
   (e) 100 °C
   (f) None of the above

5. Ultraviolet light causes the dissociation of stratospheric ozone to O₂ molecules and O atoms.
   \[ \text{O}_3(g) + \text{light} \rightarrow \text{O}_2(g) + \text{O}(g) \]
   Would you predict this reaction to be endothermic or exothermic? __________________________