CHEM 1310 Review: Reactions, Solutions, & Stoichiometry

Steps and Answer Key

1. Predict the products of the following reactions. Include the phase of each product. If there is no driving force for the reaction, write NR.

   a. $3 \text{Pb(II)(CH}_3\text{COO)}_2 (\text{aq}) + 2 \text{Na}_3\text{PO}_4 (\text{aq}) \rightarrow \text{Pb(II)(PO}_4)_2 (\text{s}) + 6 \text{NaCH}_3\text{COO (aq)}$

   b. $\text{AgNO}_2 (\text{aq}) + \text{NaCl (aq)} \rightarrow \text{AgCl (s)} + \text{NaNO}_2 (\text{aq})$

   c. $\text{NH}_3\text{OH (aq)} + \text{NaCl (aq)} \rightarrow \text{No reaction; both products are soluble}$

   d. $\text{BaI}_2 (\text{aq}) + \text{MgSO}_4 (\text{aq}) \rightarrow \text{BaSO}_4 (\text{s}) + \text{MgI}_2 (\text{aq})$

   e. $\text{CaCl}_2 (\text{aq}) + \text{NaOH (aq)} \rightarrow \text{No reaction; both products are soluble}$

2. Calcium hydroxide is formed from the reaction of calcium oxide with water. What mass of calcium hydroxide can be produced from a mixture of 25.0 g of calcium oxide and 12.0 g of water? Identify limiting and excess reagents, calculate the mass (in grams) of excess reagent remaining.

   i. Write out the reaction:

   $\text{CaO (s)} + \text{H}_2\text{O (l)} \rightarrow \text{Ca(OH)}_2 (\text{s})$

   ii. Determine moles of reactants

   
   \[
   \frac{25.0 \text{ g CaO}}{56.0774 \text{ g/mol CaO}} = 0.446 \text{ mol CaO}
   \]

   \[
   \frac{10.0 \text{ g H}_2\text{O}}{18.015 \text{ g/mol H}_2\text{O}} = 0.666 \text{ mol H}_2\text{O}
   \]

   iii. Use stoichiometric ratios to determine limiting reagent

   Since there is a 1:1 ratio between both reactants and the single product, the reactant with the smaller number of moles (CaO) is the limiting reagent.

   iv. Determine moles, mass of product from moles of limiting reagent

   Calcium oxide is the limiting reagent; the number of moles of calcium hydroxide formed is the same as the number of moles of calcium oxide used in the reaction.

   \[
   \text{mol Ca(OH)}_2 = \text{mol CaO} = 0.446 \text{ mol}
   \]

   The mass of calcium hydroxide formed can then be determined using the molar mass of the molecule:

   \[
   0.446 \text{ mol Ca(OH)}_2 \times 74.093 \text{ g/mol Ca(OH)}_2 = 33.1 \text{ g Ca(OH)}_2
   \]

   v. Determine moles, mass of excess reagent remaining from moles of limiting reagent

   If 0.466 moles of Ca(OH)$_2$ are formed, than 0.466 moles of H$_2$O, the limiting reagent, were consumed. The remaining mass of the limiting reagent is then:

   \[
   0.666 \text{ mol H}_2\text{O} - 0.466 \text{ mol H}_2\text{O} = 0.200 \text{ mol H}_2\text{O remaining}
   \]

   \[
   0.200 \text{ mol H}_2\text{O} \times 18.015 \text{ g/mol H}_2\text{O} = 3.6 \text{ g H}_2\text{O remaining}
   \]
3. 92 g of sulfur hexafluoride is produced from the reaction of sulfur in excess fluorine. If this corresponds to an 18% yield, what mass of sulfur was used for the reaction? Hint: Determine the theoretical yield of sulfur hexafluoride.

\[ S (s) + 3 \text{F}_2 (g) \rightarrow \text{SF}_6 (g) \]

i. The mass of the product is given, as well as a corresponding percent yield. First, find the theoretical yield of sulfur hexafluoride.

\[
\text{theoretical yield} = \frac{\text{92 g}}{0.18} = 511.11 \text{ g SF}_6
\]

ii. With the theoretical yield, the moles of product for a 100% yield can be determined. This value can be used with the molar ratios of the reaction, given in the problem, to determine the moles of reactant.

\[
\frac{511.11 \text{ g SF}_6}{146.055 \text{ g mol SF}_6} = 3.50 \text{ mol SF}_6
\]

\[
1 \text{ mol SF}_6 = 1 \text{ mol S}
\]

iii. Finally, the mass of sulfur used for the reaction can be determined.

\[
3.50 \text{ mol S} \times 23.065 \text{ g mol}^{-1} \text{ S} = 112.2 \text{ g S}
\]

4. What is the minimum volume of 1.1 M NaOH that must be reacted with excess chlorine gas to yield 2.2 grams of sodium hypochlorite?

\[ 2 \text{NaOH (aq) + Cl}_2 (g) \rightarrow \text{NaClO (aq) + NaCl (aq) + H}_2\text{O (l)} \]

i. Balance the given reaction!

ii. This problem gives the desired yield: 2.2 g of NaClO. First, find the number of moles of NaClO desired.

\[
\frac{2.2 \text{ g NaClO}}{74.4422 \text{ g mol NaClO}} = 0.0296 \text{ mol NaClO}
\]

iii. With a 2:1 stoichiometric ratio, the number of moles of NaOH required for the reaction is twice the number of moles of NaClO desired.

\[
\text{mol NaOH} = 2 \times \text{mol NaClO} = 0.0592 \text{ mol NaOH}
\]

iv. Finally, use the number of moles of NaOH to find the volume of 1.1 M solution that must be reacted.

\[
\frac{0.0592 \text{ mol NaOH}}{1.1 \text{ M}} = 0.0537 \text{ L} = 53.7 \text{ mL solution}
\]

5. Calcium chloride is reacted with silver nitrate.
a. Write the balanced reaction, and net ionic equations. Include the phase of each product.

Full reaction:
\[
\text{Ca(Cl)}_2 (\text{aq}) + 2 \text{AgNO}_3 (\text{aq}) \rightarrow \text{Ca(NO}_3)_2 (\text{aq}) + 2 \text{AgCl (s)}
\]

Net ionic equation:
\[
2 \text{Cl}^- (\text{aq}) + 2 \text{Ag}^+ (\text{aq}) \rightarrow 2 \text{AgCl (s)}
\]

b. If exactly 1.4 g of solid is formed, what mass of each reactant was used?

i. Determine moles of AgCl formed:
\[
\frac{1.4 \text{ g AgCl}}{143.321 \text{ g mol AgCl}} = 0.0098 \text{ mol AgCl}
\]

ii. Using stoichiometric ratios, determine moles of reactants:
- 2 mol AgCl = 1 mol Ca(Cl)_2
- 0.0098 mol AgCl = 0.0049 mol Ca(Cl)_2
- 2 mol AgCl = 2 mol AgNO_3
- 0.0098 mol AgCl = 0.0098 mol AgNO_3

iii. Determine mass of reactants used:
\[
0.0049 \text{ mol Ca(Cl)}_2 \times 110.984 \frac{\text{g}}{\text{mol}} Ca(Cl)_2 = 0.542 \text{ g Ca(Cl)}_2
\]
\[
0.0098 \text{ mol AgNO}_3 \times 169.873 \frac{\text{g}}{\text{mol}} AgNO_3 = 1.66 \text{ g AgNO}_3
\]

c. Which reactant is limiting?

The limiting reactant has the smaller number of moles. For this reaction, calcium chloride is the limiting reactant.

d. If 2.0 mL of each reactant was used, what are the molarities of the calcium chloride and silver nitrate solutions?

The molarity of each solution can be determined as the number of moles of reactant over the liters of product used:
\[
\frac{0.0049 \text{ mol Ca(Cl)}_2}{2.0 \text{ mL} \times \frac{1 \text{ L}}{1000 \text{ mL}}} = 2.44 \text{ M Ca(Cl)}_2
\]
\[
\frac{0.0098 \text{ mol AgNO}_3}{2.0 \text{ mL} \times \frac{1 \text{ L}}{1000 \text{ mL}}} = 4.88 \text{ M AgNO}_3
\]

e. If 2.0 mL of 1.2 M calcium chloride is reacted with excess silver nitrate, what is the theoretical yield of the solid product?

i. Determine moles of calcium chloride used:
\[
\frac{x \text{ mol Ca(Cl)}_2}{2.0 \text{ mL} \times \frac{1 \text{ L}}{1000 \text{ mL}}} = 1.2 \text{ M Ca(Cl)}_2
\]
1.2 M * 0.002 L = 0.0024 mol Ca(Cl)$_2$

ii. Using stoichiometric ratios, determine moles of the product:

\[
1 \text{ mol Ca(}Cl)_2 = 2 \text{ mol AgCl} \\
0.0024 \text{ mol Ca(}Cl)_2 = 0.0048 \text{ mol AgCl}
\]

iii. Finally, convert from moles to mass:

\[
0.0048 \text{ mol AgCl} \times 143.321 \frac{g}{mol} \text{AgCl} = 0.69 \text{ g AgCl}
\]

6. What is the difference between a strong, a weak, and a nonelectrolyte? Give an example of each.

A strong electrolyte dissociates completely in water. These are strong acids, strong bases, and soluble salts (ex sodium chloride).

A weak electrolyte dissociates only a small amount in water (usually less than 10%). These are weak acids and weak bases (ex acetic acid).

A nonelectrolyte does not dissociate in water. These are covalent molecules (ex sugar).

7. If 100.0 mL of acetic acid is titrated to equilibrium with 10.0 mL of 1 M KOH, what is the concentration (in units of molarity) of the acetic acid solution?

i. Write out the reaction:

\[
\text{CH}_3\text{COOH (aq) + KOH (aq)} \rightarrow \text{KCH}_3\text{COO (aq) + H}_2\text{O}
\]

ii. At equilibrium, with a 1:1 stoichiometric ratio, the number of moles of KOH titrated is the same as the number of moles of acetic acid in the original solution.

\[
\frac{x \text{ mol KOH}}{10.0 \text{ mL} \times \frac{1 \text{ L}}{1000 \text{ mL}}} = 1 \text{ M KOH}
\]

\[
\text{mol acetic acid} = \text{mol KOH} = 1 \text{ M} \times 0.01 \text{ L} = 0.01 \text{ mol}
\]

iii. The concentration of the acetic acid solution can then be determined as moles / volume:

\[
\frac{0.01 \text{ mol acetic acid}}{100.0 \text{ mL} \times \frac{1 \text{ L}}{1000 \text{ mL}}} = 0.1 \text{ M acetic acid}
\]