AP Chemistry Study Guide: Unit 4

1. Identify the limiting reactant when 65.14 g of calcium chloride reacts with 74.68 g of sodium carbonate in a double replacement reaction.

2. The arthritis drug Celebrex is a *selective* inhibitor of the enzyme that causes inflammation in humans and consequently has very few, if any, of the side effects associated with traditional non-steroidal anti-inflammatory drugs, NSAIDs (these compounds also inhibit enzymes responsible for non-inflammatory processes). It has therefore found widespread use in patients suffering from many inflammatory disorders. Celebrex's molecular formula is $C_{17}H_{14}N_3SO_2F_3$.

    a. Calculate the molecular mass and percent composition by mass of each element in Celebrex

    b. This anti-inflammatory agent is synthesized from the condensation of 4-sulphonamidophenyl hydrazine, $C_6H_9N_3SO_2$, and the Claisen condensation product of 4-methly acetophenone and ethyl trifluoroacetate, $C_{11}H_9O_2F_3$ according to the following reaction:

    $$C_6H_9N_3SO_2 + C_{11}H_9O_2F_3 \quad ---> \quad C_{17}H_{14}N_3SO_2F_3 + 2H_2O$$

    Suppose that a chemist sets up a reaction to prepare Celebrex by combining 20.0 g of each of the above reactants. How much of the anti-inflammatory compound could be synthesized from this reaction? Express you answer in grams and moles.

    c. Which reactant is in excess? Which is limiting?

    d. By what amount, expressed in grams and moles, is the excess reactant in excess?

    e. Suppose the chemist isolates 28.0 g of the purified drug from this reaction. What is the percent yield for this process?

3. A student is assigned the task of determining the mass percent of silver in an alloy of copper and silver by dissolving a sample of the alloy in excess nitric acid and then precipitating the silver as AgCl. First the student prepares 50. mL of 6.0 M HNO_3.

    a. The student is provided with a stock solution of 16 M HNO_3, two 100 mL graduated cylinders that can be read to ± 1 mL, a 100 mL beaker that can be read to ± 10 mL, a 50.0 mL volumetric flask that can be read to ± 0.06 mL, safety goggles, rubber gloves, a glass stirring rod, a dropper, and distilled H_2O.

        i. Calculate the volume, in mL, of 16 M HNO_3 that the student should use for preparing 50. mL of 6.0 M HNO_3.

        ii. Briefly list the steps of an appropriate and safe procedure for preparing the 50. mL of 6 M HNO_3. Only materials selected from those provided to the student (listed above) may be used.

    b. During the preparation of the solution, the student accidently spills about 1 mL of 16 M HNO_3 on the bench top. The student finds three bottles containing liquids sitting near the spill: a bottle of

distilled water, a bottle of 5 percent $NaHCO_{3(aq)}$, and a bottle of saturated $NaCl_{(aq)}$. Which of the liquids is best to use in cleaning up the spill? Justify your choice.

Then the student pours 25 mL of the 6 M HNO_3 into a beaker and adds a 0.6489 g sample of the alloy. Both the copper and the silver in the alloy will react with the acid. The silver reacts with nitric acid to produce silver nitrate, nitrogen dioxide, and water. After the sample completely reacts with the acid, some saturated $NaCl_{(aq)}$ solution is added to the beaker, resulting in the formation of an AgCl precipitate. Additional $NaCl_{(aq)}$ is added until no more precipitate is observed to form. The precipitate is filtered, dried, and weighed to constant mass in a filter crucible. The data are shown in the table below.

Mass of sample of copper-silver alloy	0.6489 g
Mass of dry filter, crucible	28.7210 g
Mass of filter, crucible, and precipitate (1st weighing)	29.3587 g
Mass of filter, crucible, and precipitate (2nd weighing)	29.2599 g
Mass of filter, crucible, and precipitate (3rd weighing)	29.2598 g

c. Write the balanced equation for the reaction of silver and nitric acid. Identify which species is oxidized and which is reduced in the reaction.

d. Write a molecular, complete ionic, and net ionic equation for the production of the silver chloride precipitate.

e. What was the mass of silver in the original alloy sample?

4. A sample of dolomitic limestone containing only $CaCO_3$ and $MgCO_3$ was analyzed.

   a. When a 0.2800 gram sample of this limestone was decomposed by heating, 75.0 mL of CO_2 gas at 750 mmHg and 20°C were evolved. How many grams of CO_2 were produced in this reaction?

   b. Write equations for the decomposition of <u>both</u> carbonates described above.

5. A 0.150 g sample of solid lead (II) nitrate is added to 125 mL of 0.100 M sodium iodide solution. Assume no change in volume of the solution. The chemical reaction that takes place is represented by the following equation:

$$Pb(NO_3)_2(s) + 2\ NaI(aq) \rightarrow PbI_2(s) + 2\ NaNO_3(aq)$$

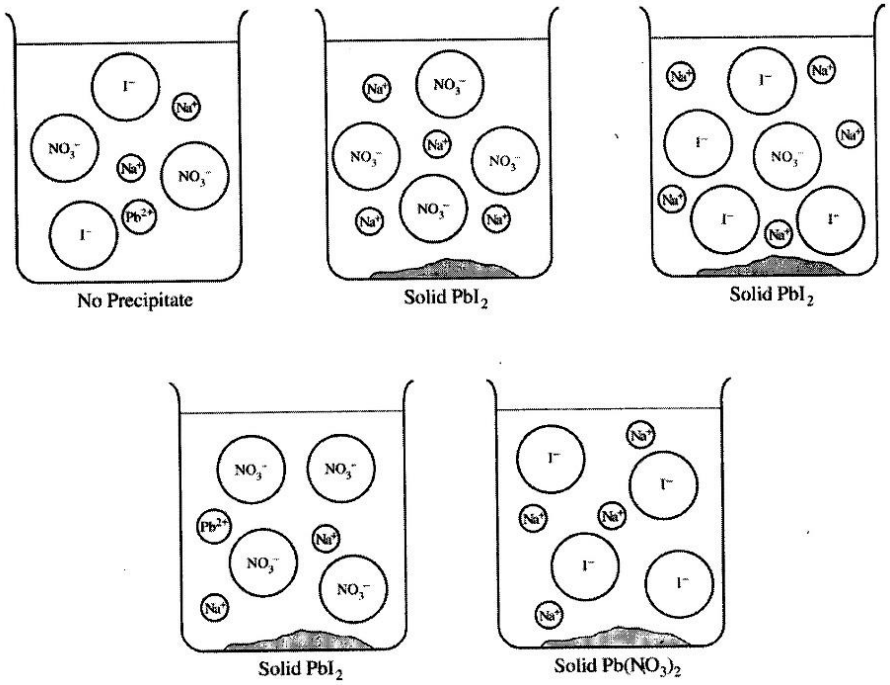
   a. List an appropriate observation that provides evidence of a chemical reaction between the two compounds.

   b. Calculate the number of moles of each reactant.

   c. Identify the limiting reactant. Show calculations to support your identification.

   d. Calculate the molar concentration of $NO_3^-(aq)$ in the mixture after the reaction is complete.

   e. Circle the diagram below that best represents the results after the mixture reacts as completely as possible. Explain the reasoning used in making your choice.



6. Small quantities of hydrogen gas can be prepared in the laboratory by the following reaction:

$$Zn(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$$

In such an experiment, 454 mL of hydrogen gas were collected over water. The temperature of this gas mixture was 23.0°C and the total pressure was 712 mmHg. What mass of zinc reacted? (The vapor pressure of water at 23.0°C is 19.8 mmHg.)

7. When 0.100 liter of 0.060 molar $Ba(NO_3)_2$ and 0.150 liter of 0.12 molar KIO_3 are mixed at 25˚C, what mass of precipitate forms? Assume that the volumes are additive.

8. Write equations for the following processes. Include states where possible.

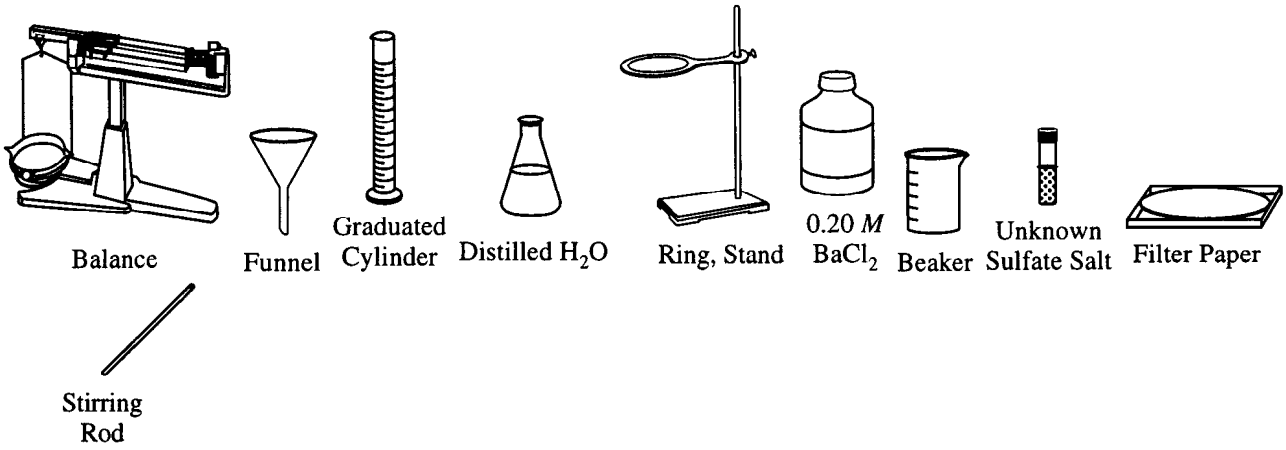
   a. The dissolving of Na_3PO_4 in water.

   b. Mixing aqueous solutions of ammonium carbonate and lead (II) nitrate.

   c. Boiling water.

   d. The combustion of methane.

9. An experiment is to be performed to determine the identity of the cation in an unknown soluble sulfate salt. The materials shown below is available for the experiment. A drying oven is also available.



a. Briefly list the steps needed to carry out this experiment.

b. Would 0.20-molar $MgCl_2$ be an acceptable substitute for the $BaCl_2$ solution provided for this experiment? Explain.

10. 15.00 mL of aqueous barium hydroxide is titrated to the equivalence point with 27.86 mL of 0.150 M hydrochloric acid. Determine the concentration of barium hydroxide solution.

11. Identify the acid, base, conjugate acid, and conjugate base:

$$H_2S(aq) + CH_3NH_2(aq) \rightleftharpoons HS^-(aq) + CH_3NH_3^+(aq)$$

12. The molecular formula of a hydrocarbon is to be determined by analyzing its combustion products.

    a. The hydrocarbon burns completely, producing 7.2 grams of water and 7.2 liters of CO_2 at standard conditions. What is the empirical formula of the hydrocarbon?

    b. Calculate the mass in grams of O_2 required for the complete combustion of the sample of the hydrocarbon described in (a).

13. The amount of iron in a soluble iron (II) compound is measured using a titration based on the equation below:

$$Fe^{2+}_{(aq)} + MnO_4^{-1}{}_{(aq)} \rightarrow Fe^{3+}_{(aq)} + Mn^{2+}_{(aq)}$$

    a. Balance the above redox reaction in acid and write it in the space below. Write the balanced equation neatly – re-write it if necessary. Circle the final balanced equation.

    b. Identify the species that is oxidized and the species that is reduced.

    c. A 22.50 mL sample of the iron (II) compound is titrated to the end point with 37.93 mL of 0.1350 M permanganate solution. Calculate the concentration of the iron (II) compound.

Practice AP questions

Answer the multiple choice questions without a calculator!

1. What is the maximum number of moles of Al_2O_3 that can be produced by the reaction of 0.40 mol of Al with 0.40 mol of O_2?

   a. 0.10 mol
   b. 0.20 mol
   c. 0.27 mol
   d. 0.33 mol
   e. 0.40 mol

2. $Zn(s) + H^+(aq) + NO_3^-(aq) \rightarrow Zn^{2+}(aq) + NH_4^+(aq) + H_2O(l)$
   When the equation above is balanced and all coefficients are reduced to lowest whole number terms, the coefficient for Zn(s) is

   a. 2
   b. 4
   c. 6
   d. 10
   e. 14

3. A student mixes equal volumes of 1.0 M solutions of tin(II) chloride and copper(II) sulfate and observes that no precipitate forms. Then the student mixes equal volumes of 1.0 M solutions of zinc(II) sulfate and tin(II) fluoride and observes the formation of a precipitate. The formula of the precipitate must be

   a. SnF_2
   b. $SnSO_4$
   c. $Sn(SO_4)_2$
   d. ZnF
   e. ZnF_2

4. When 8.0 g of N_2H_4 (32 g mol^{-1}) and 92 g of N_2O_4 (92 g mol^{-1}) are mixed together and react according to the equation below, what is the maximum mass of H_2O that can be produced?

   $$2\ N_2H_4(g) + N_2O_4(g) \rightarrow 3\ N_2(g) + 4\ H_2O(g)$$

   a. 9.0 g
   b. 18 g
   c. 36 g
   d. 72 g
   e. 144 g

5. A 2.0 L sample of an aqueous solution contains 0.10 mol of KCl and 0.10 mol of $MgCl_2$. What is the minimum number of moles of $AgNO_3$ that must be added to the solution in order to precipitate all of the Cl^- as AgCl(s)? (Assume that AgCl is insoluble.)

   a. 0.10 mol
   b. 0.20 mol
   c. 0.30 mol
   d. 0.40 mol
   e. 0.60 mol

6. What is the final concentration of barium ions, $[Ba^{2+}]$, in solution when 100. mL of 0.10 M $BaCl_2(aq)$ is mixed with 100. mL of 0.050 M $H_2SO_4(aq)$?

a. 0.00 M
b. 0.012 M
c. 0.025 M
d. 0.075 M

7. What volume of 0.150-molar HCl is required to neutralize 25.0 millilters of 0.120-molar $Ba(OH)_2$?

a. 20.0 mL
b. 30 0 mL
c. 40.0 mL
d. 60.0 mL
e. 80.0 mL

8. A 40.0 mL sample of 0.25 M KOH is added to 60.0 mL of 0.15 M $Ba(OH)_2$. What is the molar concentration of $OH^-(aq)$ in the resulting solution? (Assume that the volumes are additive)

a. 0.10 M
b. 0.19 M
c. 0.28 M
d. 0.40 M
e. 0.55 M

9. Contains an element in a +1 oxidation state

a. CO_2
b. PbO_2
c. CaO
d. N_2O_5
e. Cu_2O

10. The percentage of silver in a solid sample is determined gravimetrically by converting the silver to $Ag^+(aq)$ and precipitating it as silver chloride. Failure to do which of the following could cause errors in the analysis?

I. Account for the mass of the weighing paper when determining the mass of the sample
II. Measure the temperature during the precipitation reaction
III. Wash the precipitate
IV. Heat the AgCl precipitate to constant mass

a. I only
b. I and II
c. I and IV
d. II and III
e. I, III, and IV

Free response—calculators encouraged!

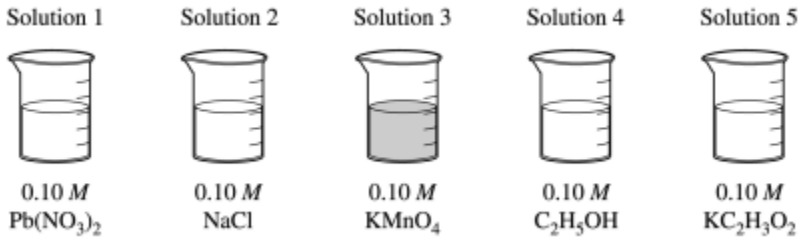
11. A 0.345 g sample of anhydrous BeC_2O_4, which contains an impurity, was dissolved to produce 100. mL of solution. 20.0 mL of this solution was titrated with $KMnO_4(aq)$. The balanced equation for the reaction that occurred is as follows:

    $$16\ H^+(aq) + 2\ MnO_4^-(aq) + 5\ C_2O_4^{2-}(aq) \rightarrow 2\ Mn^{2+}(aq) + 10\ CO_2(g) + 8\ H_2O(l)$$

    The volume of 0.0150 M $KMnO_4$(aq) required to reach the equivalence point was 17.80 mL.

    a. Identify which species is oxidized and which is reduced in the titration reaction.

    b. Calculate the mass of pure BeC_2O_4 present in the original 0.345 g impure sample.



12. Answer the questions below that relate to the five aqueous solutions at 25˚C shown above:

    a. Identify a pair of the solutions that would produce a precipitate when mixed together. Write the formula of the precipitate.

    b. Which solution would be the least effective conductor of electricity? Explain.

    c. Which solution could be used to oxidize the $Cl^-(aq)$ ion? Identify the product of oxidation.

13. Use chemical and physical principles to account for each of the following:

    a. An aluminum container filled with an aqueous solution of $CuSO_4$ eventually developed a leak. Include a chemical equation with your answer.

    b. The inside of a metal container was cleaned with steam and immediately sealed. Later, the container imploded.

    c. Skin feels cooler after rubbing alcohol has been applied to it.

d. The redness and itching of the skin caused by ant bites (injections of methanoic acid, HCO_2H) can be relieved by applying a paste made from water and baking soda (solid sodium hydrogen carbonate). Include a chemical equation with your answer.

14. A student dissolved 1.625 g of pure acetylsalicylic acid (aspirin) in distilled water and titrated the resulting solution to the equivalence point using 88.43 mL of 0.102 M NaOH(*aq*). Assuming that acetylsalicylic acid has only one ionizable hydrogen, calculate the molar mass of the acid.

15. Oxalic acid, $H_2C_2O_4$, is a primary standard used to determine the concentration of potassium permanganate, $KMnO_4$, in solution. The equation for the reaction is as follows:

$$2\ KMnO_4(aq) + 5\ H_2C_2O_4(aq) + 3\ H_2SO_4 \rightarrow 2\ MnSO_4(aq) + 10\ CO_2(g) + 8\ H_2O(l) + K_2SO_4(aq)$$

A student dissolves a sample of oxalic acid in a flask with 30 mL of water and 2.00 mL of 3.00 M H_2SO_4. The $KMnO_4$ solution of unknown concentration is in a 25.0 mL buret. In the titration, the $KMnO_4$ solution is added to the solution containing oxalic acid.

a. What species is being oxidized in the reaction?

b. What substance indicates the observable endpoint of the titration? Describe the observation that shows the endpoint has been reached.

c. What data must be collected in the titration in order to determine the molar concentration of the unknown $KMnO_4$ solution?

d. Without doing any calculation, explain how to determine the molarity of the unknown $KMnO_4$ solution.

e. How would the calculated concentration of the $KMnO_4$ solution be affected if 40 mL of water was added to the oxalic acid initially instead of 30 mL? Explain your reasoning.