Chemical Calculations

General Chemistry Review and Practice - A

Algebraic Application, Solution Preparation and Stoichiometric Analysis and Equilibrium

Lecture Demonstration Problems:

1.) Silver jewelry is usually made from silver and copper alloys and the amount of copper in the alloy can vary considerably.

   a.) 0.135 grams of metal shavings of a silver-copper alloy was dissolved in 50 ml of concentrated nitric acid. 1.00 M KCl was added until a constant weight of solid precipitate was obtained, and then an additional 50 ml was added. Collection and drying of the ppt yielded 0.156 grams.
   b.) What was the identity of the precipitate? (AgCl, MW = 143.32)
   c.) Why was the excess KCl added after precipitation was completed?
   d.) What is the composition of the alloy? (.117 g Ag, 86.97%)
   e.) If the investigator decided to was contaminated materials from the ppt by washing in 200 ml of deionized water followed by filtration and drying, what would be the result in the composition of the alloy result? ($Ksp(AgCl) = 1.8 \times 10^{-10}$)

2.) The active ingredients of an antacid sample are magnesium hydroxide and aluminum hydroxide. Neutralization of a sample of this antacid required 48.5 ml of 0.187 M HCl. The chloride salts from this neutralization were collected by evaporation of the filtrate from the titration. The dry salts weighed 0.4200 g. What is the percent by mass of $Mg(OH)_2$ and $Al(OH)_3$ in the antacid?

3.) At 27^{o}C and 1 atm, N_2O_4 is 20% dissociated into NO_2. Find
   a.) Calculate Kp
   b.) Calculate the %dissociation at 27^{o}C and a total pressure of 0.10 atm.
   c.) Express this reaction in terms of mole fractions of species and total pressure in the system. Plot the mole fraction of N_2O_4 as a function of total pressure. Verify that this is in keeping with LaChaelier's principle.
   d.) Show that in this scheme, the initial pressure of N_2O_4 does not effect the calculations
   e.) Calculate the pressure at which the reaction will not proceed.
   f.) What is the extent of dissociation in a 69 gram sample of N_2O_4 confined in a 20 L vessel at 20^{o}C?

4.) The K_{sp}'s for $PbSO_4$ and $SrSO_4$ are 6.3×10^{-7} and 3.2×10^{-7}, respectively. If both substances are together in a saturated solution, calculate the concentration of all species.

Practice Problems:

1.)

a.) Calculate and describe how to prepare 350 ml of a 0.35 M solution of KCl from solid.

Grams KCl needed = _____

b.) Calculate the % w/v and Normality of the prepared solution.

%w/v = _____ N = _____

2.) Calculate and describe how to prepare 725 ml of 14.2 % m/v solution of Potassium Acetate, $KC_2H_3O_2$ from a concentrated solution of 56% m/m. The density of the solutions is 1.35 g/ml.

Volume of concentrate = _____ ml

3.) An alcohol solution that a chemist is working with has a volume of 3 liters and a concentration of 20% v/v. How many liters of pure alcohol must be added to the solution to obtain a 40% solution? What is the final volume?

V_{final} = _____ L

4.) Consider the reaction of Copper and Nitric Acid:

$$Cu + 4\,HNO_3 \rightarrow 2\,NO_2 + Cu^{+2} + 2\,NO_3^- + 2\,H_2O$$

A stock bottle of HNO_3 has the following label information: %m/m = 71% Sp. Gr. = 1.42 (20^oC)

a.) Calculate the Molarity, molality, Normality, % w/v and mole fraction of components in the stock HNO_3 solution. (d_{water} = 099823 @ 20^oC)

Molarity = _____ Molality = _____

Normality = _____ % w/v = _____

X_{HNO3} = _____ X_{water} = _____

b.) How many ml of the HNO_3 solution are required to dissolve 0.100 grams of Cu metal such that the HNO_3 is in 100% excess?

Vol = _____ ml

c.) How many ml of 6 M NaOH are required to neutralize the excess HNO_3?

Vol = _____ ml

5.) A solution of HCl is prepared by making a dilution of 25 ml of concentrated HCl to 500 ml of solution. The bottle label on the HCl lists the specific gravity as 1.18 and the concentration as 36% m/m.

a.) Calculate the approximate molarity of the dilute solution prepared.

M HCl (approx) = _____M

A solution of NaOH (39.997) is prepared by dissolving 3 grams of NaOH solid in water and diluting to 500 ml.

b.) Calculate the approximate molarity of the NaOH solution

M NaOH(approx) = _____ M

The NaOH solution is "standardized" by carrying out a titration with the primary standard, Potassium Acid Phthalate, (KHP), which has the molecular formula, $C_8H_5KO_4$ and a molecular weight of 204.22. The reaction between KHP and NaOH is:

$KHP + NaOH \rightarrow H_2O + NaKP(aq)$

1.428 grams of KHP was dissolved in water. The resulting solution was titrated to a phenolphthalein endpoint by the addition of 47.85 ml of the prepared NaOH solution.

c.) Calculate the concentration of the NaOH to 4 significant figures.

NaOH M = _____ M

15.00 ml of the HCl solution prepared above was titrated to a phenolphthalein endpoint with 56.12 ml of the NaOH solution.

d.) Calculate the concentration of the HCl solution to 4 significant figures.

HCl M = _____ M

1.045 grams of a sample of baking soda is dissolved in 25.0 ml of HCl solution prepared and standardized above. CO_2 gas was observed bubbling off. The major component of baking soda is Sodium bicarbonate, $NaHCO_3$.

e.) Write the reaction between $NaHCO_3$ (84.007) and HCl. What is in solution at the completion of the reaction assuming HCl to be in excess?

___ $NaHCO_3(s)$ + ____$HCl(aq) \rightarrow$

The resulting solution was back titrated with the NaOH to a phenolphthalein endpoint requiring 38.12 ml of the NaOH solution.

f.) Calculate the moles of excess HCl in the sample.

Moles XS HCl = _____ moles

g.) Calculate the % $NaHCO_3$ in the original sample.

% $NaHCO_3$ = _____

h.) Give a reasonable explanation as to why this sample was treated using a back titration rather than titrating directly with HCl. Why was excess HCl used?

6.) Consider the following gas-phase equilibrium at 900 K.

$I_2 + H_2 \Leftrightarrow 2\ HI$ $\quad K_p = 50$

a.) If the initial pressures of I_2 and H_2 are each 1.8 atm and 1.8 atm, calculate the equilibrium pressures of all species.

$P(I_2)$ = _____ $P(H_2)$ = _____ P(HI) = _____

b.) Calculate the equilibrium constant for the reaction:

$2\ HI \Leftrightarrow I_2 + H_2$

K_p = _____

7.)

a.) Ag_2SO_4 solid is allowed to come to complete saturation in water. Identify and calculate the equilibrium concentrations of all species in solution, given: $K_{sp}(Ag_2SO_4) = 1.5 \times 10^{-5}$.

Species _____ Concentration _____

Species _____ Concentration _____

b.) Calculate the concentration of all species if the saturation was allowed to take place in a solution of 0.10 M Na_2SO_4.

Species _____ Concentration _____

Species _____ Concentration _____

8.) When carrying out a solubility product problem with a common ion, it is common in Gen Chem to introduce approximations that lead to quick results. Rarely, however, are those approximations tested. Consider the general solubility of a binary substance, MX having a solubility product constant, K_{sp}.

a.) Produce a general expression for the solubility of this substance in a solution of common ion, X, having a concentration, C_x. Use the quadratic equation and solve exactly.

b.) Now, repeat the problem above, however, this time invoke the common approximation that $C_x >> s$, where s is the solubility of the substance.

c.) Now, prepare a table of values for a $C_x = 0.01$ M and K_{sp} values of 10^{-5}, 10^{-4}, 10^{-3}, 10^{-2}, and 10^{-1}. Calculate the solubility using both methods and the % error for each K_{sp} value.

9.) Consider the following gas-phase equilibrium system:

$SbCl_5(g) \leftrightarrow SbCl_3(g) + Cl_2(g)$ $\qquad K_p = 3.5 \times 10^{-4}$.
0.15 bar 0.20 bar 0.0015 bar

a.) If the initial concentrations of the components are as given above, calculate the direction in which the reaction will proceed.

b.) Calculate the equilibrium pressure of all species.

Consider now, that pure $SbCl_5(g)$ is introduced into the vessel.

c.) Express this reaction in terms of mole fractions of species and total pressure in the system.

d.) Calculate the fractions of all species at 0.1, 0.5, and 1.0 mbar total pressure.

e.) Calculate the total pressure in which the system is equimolar in all species

10.)

Consider the reaction: $CH_3CH_3(g) + N_2(g) \Leftrightarrow CH_3N_2CH_3(g)$

for which $K_c = 1.30 \times 10^2$.(**Note: K_c, NOT K_p !)** 0.406 mol of $CH_3N_2CH_3(g)$ are placed in a cylinder that is equipped with a movable piston. The temperature is 300.0 K and the barometric pressure on the piston is constant at 1.00 atm. The original volume before $CH_3N_2CH_3(g)$ begins to decompose is 10.00 L. What is the volume of the cylinder at equilibrium?

11.) A container contains CO_2 at p = 0.464 atm. When graphite is added to the container, some CO_2 is converted to CO, and at equilibrium, the total pressure is 0.746 atm.

$CO_2(g) + C(s) \Leftrightarrow 2\ CO(g)$

a.) Calculate K_p for the reaction.

b.) Express the extent of reaction in terms of K_p and the total system pressure.

c.) Express the pressures of all species in terms of extent of reaction and total pressure of the system.

d.) If the system pressure is now increased to 1.50 atm, calculate the equilibrium pressure of all species.

e.) Calculate the pressure under these conditions at which the mole fractions of CO_2 and CO are identical.