Name _____ AP Chemistry ___/___/___

Chapter 4 Collected AP Exam Free Response Questions 1980 - 2010

1981 - #3a

A 1.2156-gram sample of a mixture of $CaCO_3$ and Na_2SO_4 was analyzed by dissolving the sample and completely precipitating the Ca^{2+} as CaC_2O_4. The CaC_2O_4 was dissolved in sulfuric acid and the resulting $H_2C_2O_4$ was titrated with a standard $KMnO_4$ solution.

(a) Write the balanced equation for the titration reaction, shown balanced below.

$MnO_4^- + H_2C_2O_4 + H^+ \rightarrow Mn^{2+} + CO_2 + H_2O$

Indicate which substance is the oxidizing agent and which substance is the reducing agent.

$2MnO_4^- + 5H_2C_2O_4 + 6H^+ \rightarrow 10CO_2 + 8H_2O + 2Mn^{2+}$

MnO_4^- oxidizing agent

$H_2C_2O_4$ reducing agent

1983 - #8a & b

$Ti^{3+} + HOBr <===> TiO^{2+} + Br^-$ (in acid solution)

(a) Write the correctly balanced half-reaction and net ionic equation for the skeletal equation shown above.

$2Ti^{3+} + HOBr + H_2O \rightarrow 2TiO^{2+} + 3H^+ + Br^-$

(b) Identify the oxidizing agent and the reducing agent in this reaction.

HOBr is the oxidizing agent and Ti^{3+} is the reducing agent.

1987 - #7b & d

In 1884 the Swedish chemist Svante Arrhenius proposed that salts dissociate into two or more separate, independent, ionic fragments when they dissolve in water.

(b) Give one piece of experimental evidence that the particles formed when a salt dissolves in water are charged.

When a salt is dissolved in water the solution conducts electricity.

(d) Explain why hydrogen chloride, HCl, dissociates when it dissolves in water, but not when it dissolves in benzene.

Water, because of its polar nature, is capable of solvating the ions which results from the dissociation, whereas the non-polar benzene interacts very weakly with these ions. OR Water, because of its greater dielectic constant, is more capable of separating the ions.

1998 - #1a

Solve the following problem related to the solubility equilibria of some metal hydroxides in aqueous solution.

(a) The solubility of $Cu(OH)_2$ is 1.72×10^{-6} gram per 100. milliliters of solution at 25°C.

(i) Write the balanced chemical equation for the dissociation of $Cu(OH)_2(s)$ in aqueous solution.

$Cu(OH)_2(s) <===> Cu^{2+}(aq) + 2OH^-(aq)$

(ii) Calculate the solubility (in moles per liter) of $Cu(OH)_2$ at 25°C. **1.76×10^{-7} moles per liter**

2000 - #3

Answer the following questions about $BeC_2O_4(s)$ and its hydrate.

(a) Calculate the mass percent of carbon in the hydrated form of the solid that has the formula: $BeC_2O_4 * 3H_2O$

15.90%

(b) When heated to 220.ºC, $BeC_2O_4 * 3H_2O(s)$ dehydrates completely as represented below.

$BeC_2O_4 * 3H_2O(s) \rightarrow BeC_2O_4(s) + 3H_2O(g)$

If 3.21 g of $BeC_2O_4 * 3H_2O(s)$ is heated to 220.ºC, calculate

(i) the mass of $BeC_2O_4(s)$ formed, and, **2.06 grams**

(ii) the volume of the $H_2O(g)$ released, measured at STP. **1.43 Liters**

(c) A 0.345 g sample of anhydrous BeC_2O_4 , which contains an inert impurity, was dissolved in sufficient water to produce 100. mL of solution. A 20.0 mL portion of the 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.

(i) Identify the reducing agent in the titration reaction. **$C_2O_4^{2-}$**

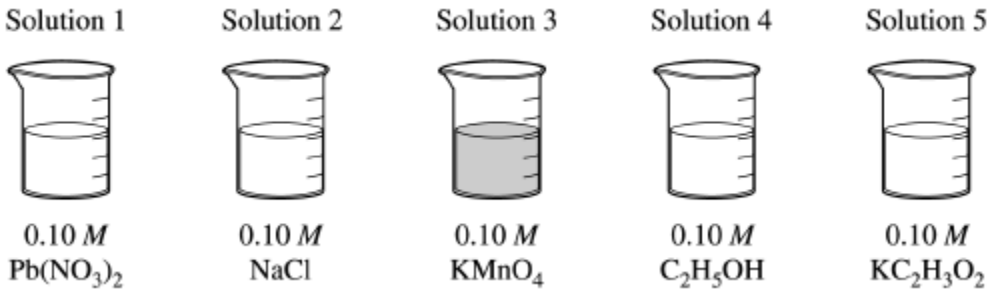
(ii) For the titration at the equivalence point, calculate the number of moles of each of the following that reacted.

(a) $MnO_4^-(aq)$ **2.67 x 10^{-4} moles MnO_4^-**
(b) $C_2O_4^{2-}(aq)$ **6.68 x 10^{-4} moles $C_2O_4^{2-}$**

(iii) Calculate the total number of moles of $C_2O_4^{2-}(aq)$ that were present in the 100. mL of prepared solution. **3.34 x 10^{-3} moles**
(iv) Calculate the mass percent of $BeC_2O_4(s)$ in the impure 0.345 g sample. **93.9%**

2001 - #1a
Answer the following questions relating to the solubility of the chlorides of silver and lead.
(a) At 10°C, $8.9x10^{-5}$ g of AgCl(*s*) will dissolve in 100. mL of water.
(i) Write the equation for the dissociation of AgCl(*s*) in water. **$AgCl(s) \rightarrow Ag^+(aq) + Cl^-(aq)$**
(ii) Calculate the solubility, in mol L^{-1}, of AgCl(*s*) in water at 10°C. **6.2 x 10^{-6} mol/L**

2001 - #5c & e



Answer the questions below that relate to the five aqueous solutions at 25ºC shown above. (2001)
(c) Identify a pair of the solutions that would produce a precipitate when mixed together. Write the formula of the precipitate. **Solution 1 & 2 will produce $PbCl_2$**
(e) Which solution would be the least effective conductor of electricity? Explain. **Solution 4 (C_2H_5OH) ethanol does not dissociate and will not conduct electricity**

2002 - #2a
Answer parts (a) through (e) below, which relate to reactions involving silver ion, Ag^+. The reaction between silver ion and solid zinc is represented by the following equation.

$2Ag^+(aq) + Zn(s) \rightarrow Zn^{2+}(aq) + 2Ag(s)$

(a) A 1.50 g sample of Zn is combined with 250. mL of 0.110 *M* $AgNO_3$ at 25°C.
(i) Identify the limiting reactant. Show calculations to support your answer. **Since only 2.75 x 10^{-2} mol Ag^+ available, Ag^+ is the limiting reactant. Calculations must be shown to support your answers.**
(ii) On the basis of the limiting reactant that you identified in part (i), determine the value of $[Zn^{2+}]$ after the reaction is complete. Assume that volume change is negligible. **0.0550 *M* Zn^{2+}**

2002B - #3a
Nitrogen monoxide, NO(*g*), and carbon monoxide, CO(*g*), are air pollutants generated by automobiles. It has been proposed that under suitable conditions these two gases could react to form $N_2(g)$ and $CO_2(g)$, which are components of unpolluted air.

(a) Write a balanced equation for the reaction described above. Indicate whether the carbon in CO is oxidized or whether it is reduced in the reaction. Justify your answer. **$2NO(g) + 2CO(g) \rightarrow N_2(g) + 2CO_2(g)$**
CO is oxidized. Carbon in CO has an oxidation number of +2 and in CO_2 carbon has an oxidation number of +4. The oxidation number increases.

2003B - #2b
In a reaction vessel, 0.600 mol of $Ba(NO_3)_2(s)$ and 0.300 mol of $H_3PO_4(aq)$ are combined with deionized water to a final volume of 2.00 L. The reaction represented below occurs.

$3Ba(NO_3)_2(aq) + 2H_3PO_4(aq) \rightarrow Ba_3(PO_4)_2(s) + 6HNO_3(aq)$

(i) Calculate the mass of $Ba_3(PO_4)_2(s)$ formed. **90.3 g $Ba_3(PO_4)_2$**

(iii) What is the concentration, in mol L^{-1}, of the nitrate ion, NO_3^- (aq), after the reaction reaches completion? **0.60 *M* NO_3^-**

2003B - #5a

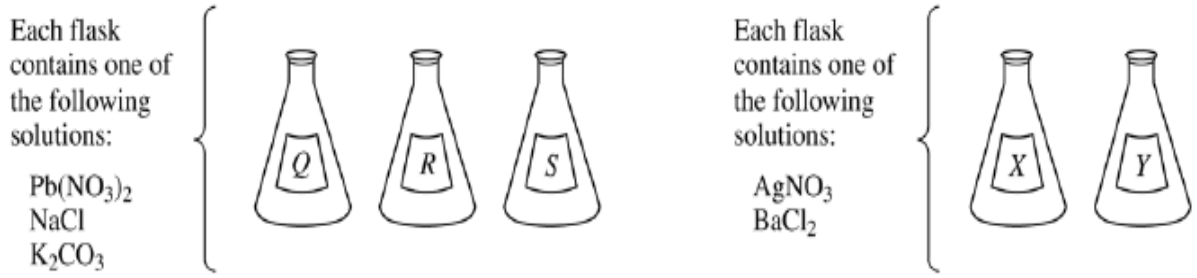
Oxalic acid, $H_2C_2O_4$, is a primary standard used to determine the concentration of potassium permanganate, $KMnO_4$, in solution. The equation for the reaction is as follows.

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

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 chemical species is being oxidized in the reaction? **$H_2C_2O_4$ is the substance being oxidized. The half-reaction is: $H_2C_2O_4(aq) \rightarrow 2CO_2(g) + 2H^+(aq) + 2e^-$**

2004 - #5



(a) When the student combined a sample of solution *Q* with a sample of solution *X* , a precipitate formed. A precipitate also formed when samples of solutions *Q* and *Y* were combined.

(i) Identify solution *Q* . **K_2CO_3**

(ii) Write the chemical formulas for each of the two precipitates. **Ag_2CO_3 + $BaCO_3$**

(b) When solution *Q* is mixed with solution *R* , a precipitate forms. However, no precipitate forms when solution *Q* is mixed with solution *S*.

(i) Identify solution *R* and solution *S*. **R = $Pb(NO_3)_2$ S = NaCl**

(ii) Write the chemical formula of the precipitate that forms when solution *Q* is mixed with solution *R*. **$PbCO_3$**

(c) The identity of solution *X* and solution *Y* are to be determined using only the following solutions: 1.0 *M* $Pb(NO_3)_2$, 1.0 *M* NaCl , and 1.0 *M* K_2CO_3 .

(i) Describe a procedure to identify solution *X* and solution *Y*. **add NaCl (aq) to each**
(alternative answer) add $Pb(NO_3)_2$ (aq) to each

(ii) Describe the observations that would allow you to distinguish between solution *X* and solution *Y*.
AgCl will form a precipitate, $BaCl_2$ will not
(alternative answer) $PbCl_2$ will precipitate, $Ba(NO_3)_2$ will not

(iii) Explain how the observations would enable you to distinguish between solution *X* and solution *Y*.
AgCl is insoluble, $BaCl_2$ is soluble (alternative answer) $Ba(NO_3)_2$ is soluble, $PbCl_2$ is insoluble

2006 - #1aii

Answer the following questions that relate to solubility of salts of lead and barium.

A saturated solution is prepared by adding excess $PbI_2(s)$ to distilled water to form 1.0 L of solution at 25°C. The concentration of $Pb^{2+}(aq)$ in the saturated solution is found to be 1.3×10^{-3} *M* . The chemical equation for the dissolution of $PbI_2(s)$ in water is shown below.

$PbI_2(s) \rightleftharpoons Pb^{2+}(aq) + 2\,I^-(aq)$

(ii) Calculate the molar concentration of $I^-(aq)$ in the solution. **2.6×10^{-3} *M***

2007 - #1c & d

$HF(aq)$ reacts with $NaOH(aq)$ according to the reaction represented below.

$HF(aq) + OH^-(aq) \rightleftharpoons H_2O(l) + F^-(aq)$

A volume of 15 mL of 0.40 *M* NaOH(*aq*) is added to 25 mL of 0.40 *M* HF(*aq*) solution. Assume that volumes are additive.

(c) Calculate the number of moles of HF(*aq*) remaining in the solution. **0.004 mol HF remain**

(d) Calculate the molar concentration of $F^-(aq)$ in the solution. **0.15 M F^-**

2007 - #5a & b

$5\ Fe^{2+}(aq) + MnO_4^-(aq) + 8\ H^+(aq) \rightarrow 5Fe^{3+}(aq) + Mn^{2+}(aq) + 4H2O(l)$

The mass percent of iron in a soluble iron(II) compound is measured using a titration based on the balanced equation above.

(a) What is the oxidation number of manganese in the permanganate ion, $MnO_4^-(aq)$? **+7**

(b) Identify the reducing agent in the reaction represented above. **Fe^{2+}**

2008B - #3

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.

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

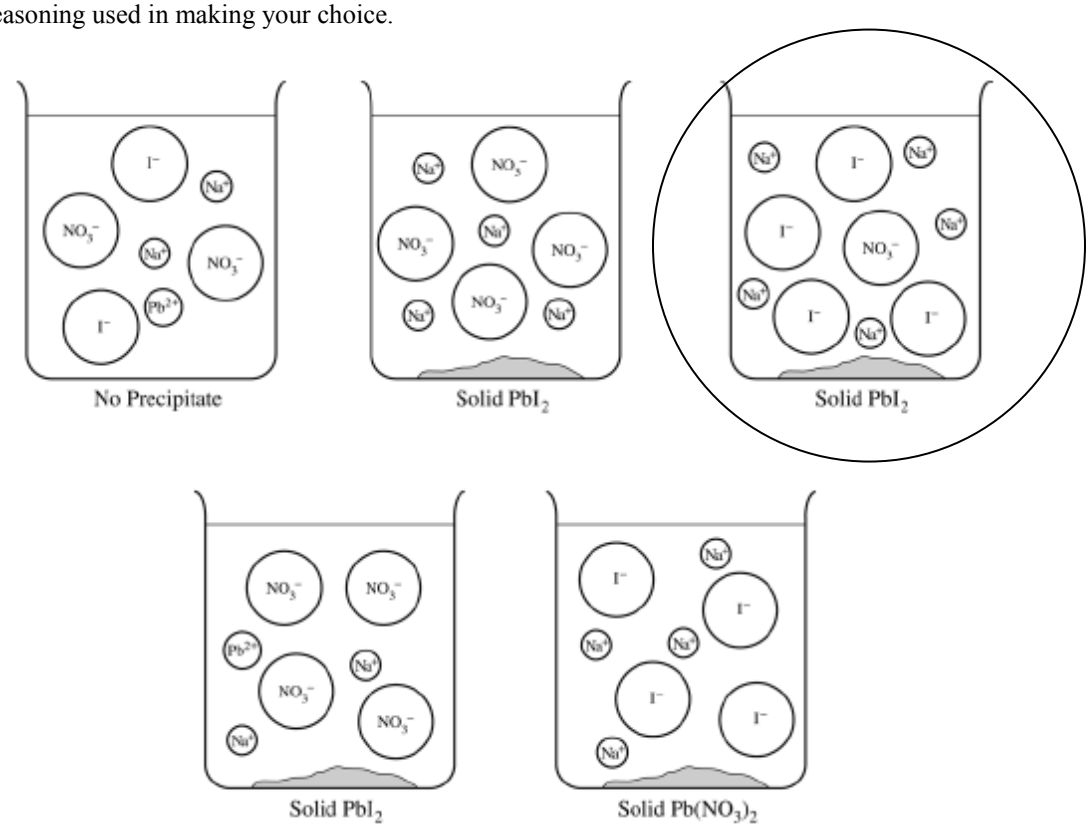
(a) List an appropriate observation that provides evidence of a chemical reaction between the two compounds. **A yellow precipitate forms.**

(b) Calculate the number of moles of each reactant. **4.53×10^{-4} moles $Pb(NO_3)_2$ 0.0125 moles NaI**

(c) Identify the limiting reactant. Show calculations to support your identification. **$Pb(NO_3)_2$ is the limiting reagent. You must show calculations to support your answer.**

(d) Calculate the molar concentration of $NO_3^-(aq)$ in the mixture after the reaction is complete. **7.25×10^{-3} M**

(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.



2010B - #3

A sample of ore containing the mineral tellurite, TeO_2, was dissolved in acid. The resulting solution was then reacted with a solution of $K_2Cr_2O_7$ to form telluric acid, H_2TeO_4. The unbalanced chemical equation for the reaction is given below.

$$\mathbf{3}\ TeO_2(s) + \mathbf{1}\ Cr_2O_7^{2-}(aq) + \mathbf{8}\ H^+(aq) \rightleftharpoons \mathbf{3}\ H_2TeO_4(aq) + \mathbf{2}\ Cr^{3+}(aq) + \mathbf{1}\ H_2O(l)$$

(a) Identify the molecule or ion that is being oxidized in the reaction. **TeO_2**

(b) Give the oxidation number of Cr in the $Cr_2O_7^{2-}(aq)$ ion. **+6**

(c) Balance the chemical equation given above by writing the correct lowest whole-number coefficients on the dotted lines.