AP® CHEMISTRY
2014 SCORING GUIDELINES

Question 1
(10 points)

Mass of KI tablet	0.425 g
Mass of thoroughly dried filter paper	1.462 g
Mass of filter paper + precipitate after first drying	1.775 g
Mass of filter paper + precipitate after second drying	1.699 g
Mass of filter paper + precipitate after third drying	1.698 g

A student is given the task of determining the I^- content of tablets that contain KI and an inert, water-soluble sugar as a filler. A tablet is dissolved in 50.0 mL of distilled water, and an excess of 0.20 M $Pb(NO_3)_2(aq)$ is added to the solution. A yellow precipitate forms, which is then filtered, washed, and dried. The data from the experiment are shown in the table above.

(a) For the chemical reaction that occurs when the precipitate forms,

(i) write a balanced, net-ionic equation for the reaction, and

$Pb^{2+} + 2\,I^- \rightarrow PbI_2$	1 point is earned for a balanced net-ionic equation.

(ii) explain why the reaction is best represented by a net-ionic equation.

The net-ionic equation shows the formation of the $PbI_2(s)$ from $Pb^{2+}(aq)$ and $I^-(aq)$ ions, omitting the non-reacting species (spectator ions), $K^+(aq)$ and $NO_3^-(aq)$.	1 point is earned for a valid explanation.

(b) Explain the purpose of drying and weighing the filter paper with the precipitate three times.

The filter paper and precipitate must be dried several times (to a constant mass) to ensure that all the water has been driven off.	1 point is earned for a valid explanation.

(c) In the filtrate solution, is $[K^+]$ greater than, less than, or equal to $[NO_3^-]$? Justify your answer.

$[K^+]$ is less than $[NO_3^-]$ because the source of the NO_3^-, the 0.20 M $Pb(NO_3)_2(aq)$, was added in excess.	1 point is earned for a correct comparison with a valid explanation.

Question 1 (continued)

(d) Calculate the number of moles of precipitate that is produced in the experiment.

$1.698 \text{ g} - 1.462 \text{ g} = 0.236 \text{ g } PbI_2(s)$ $0.236 \text{ g } PbI_2 \times \frac{1 \text{ mol } PbI_2}{461.0 \text{ g } PbI_2} = 5.12 \times 10^{-4} \text{ mol } PbI_2$	1 point is earned for the correct number of moles of $PbI_2(s)$ precipitate.

(e) Calculate the mass percent of I^- in the tablet.

$5.12 \times 10^{-4} \text{ mol } PbI_2 \times \frac{2 \text{ mol } I^-}{1 \text{ mol } PbI_2} = 1.02 \times 10^{-3} \text{ mol } I^-$ $1.02 \times 10^{-3} \text{ mol } I^- \times \frac{126.91 \text{ g } I^-}{1 \text{ mol } I^-} = 0.130 \text{ g } I^-$ in one tablet $\frac{0.130 \text{ g } I^-}{0.425 \text{ g KI tablet}} = 0.306 = 30.6\% \; I^-$ per KI tablet	1 point is earned for determining the number of moles of I^- in one tablet. 1 point is earned for calculating the mass percent of I^- in the KI tablet.

(f) In another trial, the student dissolves a tablet in 55.0 mL of water instead of 50.0 mL of water. Predict whether the experimentally determined mass percent of I^- will be greater than, less than, or equal to the amount calculated in part (e). Justify your answer.

The mass percent of I^- will be the same. $Pb^{2+}(aq)$ was added in excess, ensuring that essentially no I^- remained in solution. The additional water is removed by filtration and drying, leaving the same mass of dried precipitate.	1 point is earned for correct comparison with a valid justification.

(g) A student in another lab also wants to determine the I^- content of a KI tablet but does not have access to $Pb(NO_3)_2$. However, the student does have access to 0.20 *M* $AgNO_3$, which reacts with $I^-(aq)$ to produce $AgI(s)$. The value of K_{sp} for AgI is 8.5×10^{-17}.

(i) Will the substitution of $AgNO_3$ for $Pb(NO_3)_2$ result in the precipitation of the I^- ion from solution? Justify your answer.

Yes. Addition of an excess of 0.20 *M* $AgNO_3(aq)$ will precipitate all of the I^- ion present in the solution because AgI is insoluble, as evidenced by its low value of K_{sp}.	1 point is earned for the correct answer with a valid justification.

(ii) The student only has access to one KI tablet and a balance that can measure to the nearest 0.01 g. Will the student be able to determine the mass of AgI produced to three significant figures? Justify your answer.

Question 1 (continued)

No. If masses can be measured to ±0.01 g, then the mass of the dry AgI(*s*) precipitate (which is less than 1 g) will be known to only two significant figures.	1 point is earned for a correct answer with a valid justification.

1A, 1

(g) A student in another lab also wants to determine the I^- content of a KI tablet but does not have access to $Pb(NO_3)_2$. However, the student does have access to 0.20 *M* $AgNO_3$, which reacts with $I^-(aq)$ to produce $AgI(s)$. The value of K_{sp} for AgI is 8.5×10^{-17}

(i) Will the substitution of $AgNO_3$ for $Pb(NO_3)_2$ result in the precipitation of the I^- ion from solution? Justify your answer.

(ii) The student only has access to one KI tablet and a balance that can measure to the nearest 0.01 g. Will the student be able to determine the mass of AgI produced to three significant figures? Justify your answer.

a) i) $2I^-(aq) + Pb^{2+}(aq) \rightarrow PbI_2(s)$

ii) The reaction is best represented by a net-ionic equation because the K^+ and NO_3^- remain unchanged in solution, so the only substances that are affected by the reaction are displayed in the net-ionic equation (I^- & Pb^{2+}).

b) The filter paper & precipitate are dried and weighed three times to ensure that no water remains in the precipitate, and therefore the observed mass is only PbI_2 and filter paper, not water.

c) $[K^+] < [NO_3^-]$ because excess $Pb(NO_3)_2$ was added, meaning that $Pb(NO_3)_2$ was added with the intention of making $[NO_3^-]$ greater than $[K^+]$

d) 1.698 g − 1.462 g = 0.236 g precipitate

$0.236\,g\,PbI_2 \times \frac{1\,mol\,PbI_2}{461.02\,g\,PbI_2} = \boxed{5.12 \times 10^{-4}\text{ mol precipitate}}$

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ADDITIONAL PAGE FOR ANSWERING QUESTION 1

e) 5.12×10^{-4} mol $PbI_2 \times \frac{2 \text{ mol } I^-}{1 \text{ mol } PbI_2} \times \frac{126.91 \text{ g } I^-}{1 \text{ mol } I^-} = 0.130 \text{ g } I^-$

$\frac{0.130 \text{ g } I^-}{0.425 \text{ g KI}} = \boxed{30.6\%}$

f) The mass percent will be the same because the same amount of KI was used. The amount of water or the concentration is not used in any calculations because the precipitate was dried before it was massed.

g) i) The substitution with $AgNO_3$ will still precipitate the I^- ion because it will form AgI, which is still a solid with a very low Ksp, meaning that it will not dissociate in water.

ii) no, they will not be able to measure to 3 significant figures because after weighing out the precipitate + filter paper – filter paper, the mass will be less than 1 and will only have 2 significant figures, so all calculations will be done with 2 significant figures.

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1B1

(g) A student in another lab also wants to determine the I^- content of a KI tablet but does not have access to $Pb(NO_3)_2$. However, the student does have access to 0.20 *M* $AgNO_3$, which reacts with $I^-(aq)$ to produce $AgI(s)$. The value of K_{sp} for AgI is 8.5×10^{-17}.

(i) Will the substitution of $AgNO_3$ for $Pb(NO_3)_2$ result in the precipitation of the I^- ion from solution? Justify your answer.

(ii) The student only has access to one KI tablet and a balance that can measure to the nearest 0.01 g. Will the student be able to determine the mass of AgI produced to three significant figures? Justify your answer.

a) $2KI + Pb(NO_3)_2 \rightarrow PbI_2 + 2KNO_3$

i) $2I^-(aq) + Pb^{2+}(aq) \rightarrow PbI_2(s)$

ii) The reaction is best represented in a net ionic equation because the thing the student is looking for is the precipitate (PbI_2).

b) The drying is to make sure no water is left and it is done three times to make sure all water is removed.

c) $[K^+] < [NO_3^-]$ because the $Pb(NO_3)_2$ is in excess.

d) $1.698g - 1.462g = .236\ g\ PbI_2$

$$\frac{.236g\ PbI_2}{} \left| \frac{1 mol\ PbI_2}{461.0g\ PbI_2} \right. = 5.12 \times 10^{-4}\ mol\ PbI_2$$

e) $$5.12 \times 10^{-4}\ mol\ PbI_2 \left| \frac{2 mol}{1 mol} \right| \frac{126.9g}{1 mol} = \frac{.130}{.425} \times 100 = 30.6\%$$

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1B2

ADDITIONAL PAGE FOR ANSWERING QUESTION 1

f) The mass percent of I^- would be equal to part (e) because the addition of water has no effect on the reaction or experiment.

g) i) yes because AgI(s) is a solid
ii) no because the balance only calculates for two sig figs and one tablet is .425 g or .43g on the balance available.

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1C1

(g) A student in another lab also wants to determine the I^- content of a KI tablet but does not have access to $Pb(NO_3)_2$. However, the student does have access to 0.20 M $AgNO_3$, which reacts with $I^-(aq)$ to produce $AgI(s)$. The value of K_{sp} for AgI is 8.5×10^{-17}.

(i) Will the substitution of $AgNO_3$ for $Pb(NO_3)_2$ result in the precipitation of the I^- ion from solution? Justify your answer.

(ii) The student only has access to one KI tablet and a balance that can measure to the nearest 0.01 g. Will the student be able to determine the mass of AgI produced to three significant figures? Justify your answer.

ai) $2KI + Pb(NO_3)_2 \rightarrow 2KNO_3 + PbI_2 \Rightarrow$ [crossed out]

$2I^- + Pb^{2+} \rightarrow PbI_2$

aii) in a net ionic equation - all the soluble substances are cancelled out so that only the insoluble remain in the equation therefore that would be useful here because the precipitate is being observed.

b) To make sure that all excess water & solution are removed because if it weren't it could cause error in calculation by making the mass of the precipitate greater than what it's supposed to be.

c) $[K^+] = [NO_3^-]$ 1 mole of KNO_3 produces 1 mole each of K^+ and NO_3^- so concentrations would be equal

d) mass of filter paper + precipitate (after 3rd drying) − mass of dried filterpaper

1.698 g − 1.462 g = 0.236 g of precipitate

$PbI_2 = 207 + 2(127) = 461$ g/mol

0.236 g precip. $\left(\frac{1 \text{ mol}}{461 \text{ g}}\right) = 5.119 \times 10^{-4}$ mol PbI_2 (precipitate)

e) $KI = 39 + 127 = 166$ g/mol $\qquad KI \rightarrow K^+ + I^-$

$0.425 \text{ g KI} \left(\frac{1 \text{ mol KI}}{166 \text{ g}}\right)\left(\frac{1 \text{ mol } I^-}{1 \text{ mol KI}}\right)\left(\frac{127 \text{ g}}{1 \text{ mol } I^-}\right) = 0.325 \text{ g } I^-$

$\frac{0.325 \text{ g } I^-}{0.425 \text{ g KI}} \times 100\% = 76.5\%$

f) The mass percent of I^- would still be the same because as the mass of I^- decreases as volume of water increases - so do the other ions therefore same ratio/percent value.

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1C 2

ADDITIONAL PAGE FOR ANSWERING QUESTION 1

g) ~~K~~I + Ag~~NO~~3 → ~~KNO~~3 + AgI   [$AgNO_3$] = 0.20 M

$I^- + Ag^+ \rightarrow AgI$ [Ag^+] = 0.20M

[NO_3^-] = 0.20 M

Ksp = 8.5×10^{-7}

~~Ksp = [AgI] / [Ag+][I-] = (0.20)(~~

No because the conc. of NO_3^- is smaller in ~~PbNO~~ $AgNO_3$ than $Pb(NO_3)_2$ therefore less can be consumed to produce I^- in the reaction.

g ii) no because ~~it can~~ the balance can only measure up to 0.~~00~~01 g which is only 2 sigfigs.
The smallest number of sigfigs is the maximum number of sigfigs that can be obtained in the end so no - 3 sigfigs can't be obtained.

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Question 1

Overview

This question assesses students' understanding of the principles and practice of gravimetric analysis. Students are presented with data from an experiment precipitating $I^{-}(aq)$ from a solution prepared by dissolving a tablet containing KI and an inert, water-soluble sugar using excess $Pb(NO_3)_2(aq)$. Part (a) asks the students to write the net-ionic equation for the reaction that occurs, and to explain why the net-ionic equation is the best representation of the reaction. Parts (b) and (c) assess the students' understanding of the design and implementation of the experiment – students are asked to explain the reason for repeated drying and weighing of the precipitate and to demonstrate an understanding of the composition of the filtrate. In parts (d) and (e), the students are required to use the given data to determine, ultimately, the mass percent of I^{-} in the tablet. Part (f) again assesses experimental design, and asks the student to predict how a change in the experimental procedure (dissolving the tablet in 55.0 mL of solution rather than 50.0 mL) will affect the results and to justify their prediction. Finally, in part (g), a similar experiment is described using 0.20 M $AgNO_3(aq)$ rather than 0.20 M $Pb(NO_3)_2(aq)$. In part (g)(i), students were given the value of the K_{sp} of AgI and asked to predict if the addition of 0.20 M $AgNO_3(aq)$ would precipitate I^{-} from the solution. Part (g)(ii) asks how the precision of the experimental mass of AgI precipitate would be affected if the experimenter had access only to one tablet and to a balance that can measure to the nearest 0.01 g.

Sample: 1A
Score: 10

This response earned all 10 possible points: 1 point in part (a)(i), 1 point in part (a)(ii), 1 point in part (b), 1 point in part (c), 1 point in part (d), 2 points in part (e), 1 point in part (f), 1 point in part (g)(i), and 1 point in part (g)(ii).

Sample: 1B
Score: 7

All possible points were earned in parts (a)(i), (a)(ii), (b), (c), (d), and (e). No credit was earned for part (f); although the student recognizes that the addition of 5.0 more milliliters of water will not affect the mass percent I^{-}, the response simply restates this without sufficient justification. No credit was earned in part (g)(i) because the response states that AgI is a solid, but does not address the solubility of AgI in water. Part (g)(ii) did not earn credit because the response discusses the mass of the tablet rather than the mass of the AgI precipitate.

Sample: 1C
Score: 5

All possible points were earned in parts (a)(i), (a)(ii), (b), and (d). No credit was earned in part (c) for an incorrect comparison of $[K^{+}]$ and $[NO_3^{-}]$ that is based on reaction stoichiometry rather than the experimental design. The first point was not earned in part(e), but the second point was earned for dividing an (incorrect) mass of I^{-} by the mass of the tablet and converting to a percent I^{-}. No credit was earned in part (f) for an incorrect explanation. Credit was not earned in part (g)(i) because the response claims that I^{-} will not be precipitated from the solution by 0.20 M $AgNO_3(aq)$. No credit was earned in part (g)(ii) because no reference was made to the mass of the AgI precipitate.