Key

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2009 SCORING GUIDELINES

Question 4 (15 points)

(a) A sample of solid iron(III) oxide is reduced completely with solid carbon.

(i) Balanced equation: $2\ Fe_2O_3 + 3\ C \rightarrow 4\ Fe + 3\ CO_2$ **OR** $Fe_2O_3 + 3\ C \rightarrow 2\ Fe + 3\ CO$	One point is earned for both correct reactants. Two points are earned for the correct products (1 point each). One point is earned for correctly balancing (mass and charge) the equation.

(ii) What is the oxidation number of carbon before the reaction, and what is the oxidation number of carbon after the reaction is complete?

The oxidation number of C before the reaction is 0, and the oxidation number of C after the reaction is +4.	One point is earned for both oxidation numbers consistent with part (i).

(b) Equal volumes of equimolar solutions of ammonia and hydrochloric acid are combined.

(i) Balanced equation: $NH_3 + H^+ \rightarrow NH_4^+$ **OR** $NH_3 + H_3O^+ \rightarrow NH_4^+ + H_2O$	Two points are earned for the correct reactants. One point is earned for the correct product(s). One point is earned for correctly balancing (mass and charge) the equation.

(ii) Indicate whether the resulting solution is acidic, basic, or neutral. Explain.

The resulting solution is acidic because of the hydrolysis of the NH_4^+ ion, which reacts with water to form NH_3 and H^+. **OR** The mixing of a strong acid and a weak base results in an acidic solution.	One point is earned for a correct answer consistent with part (i).

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Question 4 (continued)

(c) Solid mercury(II) oxide decomposes as it is heated in an open test tube in a fume hood.

(i) Balanced equation: $2\ HgO \rightarrow 2\ Hg + O_2$	One point is earned for the correct reactant. Two points are earned for the correct products (1 point each). One point is earned for correctly balancing (mass and charge) the equation.

(ii) After the reaction is complete, is the mass of the material in the test tube greater than, less than, or equal to the mass of the original sample? Explain.

The mass of the contents of the test tube will decrease owing to the loss of O_2 gas to the atmosphere.	One point is earned for a correct answer consistent with part (i).

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Question 4 (15 points)

(a) A barium nitrate solution and a potassium fluoride solution are combined and a precipitate forms.

(i) Balanced equation: $Ba^{2+} + 2\,F^- \rightarrow BaF_2$	Two points are earned for the correct reactants (1 point each). One point is earned for the correct product. One point is earned for correctly balancing the equation for atoms and charge.

(ii) If equimolar amounts of barium nitrate and potassium fluoride are combined, which reactant, if any, is the limiting reactant? Explain.

According to the balanced chemical equation, twice as much potassium fluoride is required to completely react with the barium nitrate. Because there are equimolar amounts of barium nitrate and potassium fluoride, there is not enough potassium fluoride to react with all of the barium nitrate, so potassium fluoride is the limiting reactant.	One point is earned for a correct answer that is consistent with part (i).

(b) A piece of cadmium metal is oxidized by adding it to a solution of copper(II) chloride.

(i) Balanced equation: $Cd + Cu^{2+} \rightarrow Cd^{2+} + Cu$	One point is earned for <u>both</u> correct reactants. One point is earned for <u>both</u> correct products. One point is earned for correctly balancing the equation for atoms and charge.

(ii) List two visible changes that would occur in the reaction container as the reaction is proceeding.

In the solution, the blue color of the copper(II) cation would decrease, and eventually the solution would become colorless. Reddish-brown (or black) copper metal would plate out onto the piece of silvery cadmium metal.	Two points are earned for correctly describing the changes (1 point each).

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Question 4 (continued)

(c) A hydrolysis reaction occurs when solid sodium sulfide is added to distilled water.

(i) Balanced equation: $Na_2S + H_2O \rightarrow 2\,Na^+ + HS^- + OH^-$ **OR** $Na_2S + 2\,H_2O \rightarrow 2\,Na^+ + H_2S + 2\,OH^-$	One point is earned for <u>both</u> correct reactants. One point is earned for any <u>two</u> correct products; 2 points are earned for all <u>three</u> correct products. One point is earned for correctly balancing the equation for atoms and charge.

(ii) Indicate whether the pH of the resulting solution is less than 7, equal to 7, or greater than 7. Explain.

The pH of the resulting solution is greater than 7. The hydrolysis reaction of S^{2-} produces the base OH^-, thus raising the pH above 7.	One point is earned for a correct answer that is consistent with part (i).

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Question 4
(15 points)

(a) Zinc metal is added to a hydrobromic acid solution.

Balanced equation: $Zn + 2\,H^+ \rightarrow Zn^{2+} + H_2$	1 point is earned for the correct reactants. 2 points are earned for the correct products. 1 point is earned for the balanced equation.

(ii) Write the oxidation half-reaction for the reaction.

$Zn \rightarrow Zn^{2+} + 2\,e^-$	1 point is earned for the balanced half-reaction.

(b) Solid lithium oxide is added to distilled water.

Balanced equation: $Li_2O + H_2O \rightarrow 2\,Li^+ + 2\,OH^-$	1 point is earned for the correct reactants. 2 points are earned for the correct products. 1 point is earned for the balanced equation.

(ii) Indicate whether the pH of the resulting solution is less than 7, equal to 7, or greater than 7. Explain.

The pH of the resulting solution would be greater than 7 because OH^-, a strong base, is formed in the reaction.	1 point is earned for the correct answer.

(c) A 100 mL sample of 1 *M* strontium chloride solution is mixed with a 100 mL sample of 1 *M* sodium carbonate solution, resulting in the formation of a precipitate.

Balanced equation: $Sr^{2+} + CO_3^{2-} \rightarrow SrCO_3$	2 points are earned for the correct reactants. 1 point is earned for the correct product. 1 point is earned for the balanced equation.

(ii) Describe what will occur if the precipitate is dried and a few drops of 1 *M* hydrochloric acid are added. Explain.

The precipitate disappears and bubbles of CO_2 form.	1 point is earned for a correct answer.

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Question 4
(15 points)

(a) A piece of solid strontium carbonate is dropped into a 0.1 *M* solution of hydrochloric acid.

(i) Balanced equation: $2\ H^+ + SrCO_3 \rightarrow Sr^{2+} + CO_2 + H_2O$ OR, $H^+ + SrCO_3 \rightarrow Sr^{2+} + HCO_3^-$	1 point is earned for the correct reactants. 2 points are earned for the correct products. 1 point is earned for correctly balancing the equation for mass and charge.

(ii) Indicate one thing that would be observed as the reaction occurs.

The solid dissolves OR a gas is given off.	1 point is earned for either observation.

(b) Magnesium metal is strongly heated in oxygen gas.

(i) Balanced equation: $2\ Mg + O_2 \rightarrow 2\ MgO$	2 points are earned for the correct reactants. 1 point is earned for the correct product. 1 point is earned for correctly balancing the equation for mass and charge.

(ii) What is the oxidation number of magnesium before the reaction occurs, and what is the oxidation number of magnesium after the reaction is complete?

Oxidation number before = 0. Oxidation number after = +2.	1 point is earned for two correct responses.

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Question 4 (continued)

(c) A solution of nickel(II) chloride is added to a solution of sodium hydroxide, forming a precipitate.

(i) Balanced equation: $Ni^{2+} + 2\ OH^- \rightarrow Ni(OH)_2$	2 points are earned for the correct reactants. 1 point is earned for the correct product. 1 point is earned for correctly balancing the equation for mass and charge.

(ii) If equal volumes of 1.0 *M* nickel (II) chloride and 1.0 *M* sodium hydroxide are used, what ion is present in the solution in the highest concentration after the precipitate forms?

The chloride ion	1 point is earned for the correct ion.

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Question 2

Answer the following questions relating to gravimetric analysis.

In the first of two experiments, a student is assigned the task of determining the number of moles of water in one mole of $MgCl_2 \cdot n\,H_2O$. The student collects the data shown in the following table.

Mass of empty container	22.347 g
Initial mass of sample and container	25.825 g
Mass of sample and container after first heating	23.982 g
Mass of sample and container after second heating	23.976 g
Mass of sample and container after third heating	23.977 g

(a) Explain why the student can correctly conclude that the hydrate was heated a sufficient number of times in the experiment.

No additional mass was lost during the third heating, indicating that all the water of hydration had been driven off.	One point is earned for the correct explanation.

(b) Use the data above to

(i) calculate the total number of moles of water lost when the sample was heated, and

mass of H_2O lost $= 25.825 - 23.977 = 1.848$ g *OR* $25.825 - 23.976 = 1.849$ g $1.848\text{ g } H_2O \times \frac{1\text{ mol } H_2O}{18.02\text{ g } H_2O} = 0.1026\text{ mol } H_2O$	One point is earned for calculating the correct number of moles of water.

(ii) determine the formula of the hydrated compound.

mass of anhydrous $MgCl_2 = 23.977 - 22.347 = 1.630$ g $1.630\text{ g } MgCl_2 \times \frac{1\text{ mol } MgCl_2}{95.20\text{ g } MgCl_2} = 0.01712\text{ mol } MgCl_2$ $\frac{0.1026\text{ mol } H_2O}{0.01712\text{ mol } MgCl_2} = 5.993 \approx 6\text{ mol } H_2O \text{ per mol } MgCl_2$ $\Rightarrow$ formula is $MgCl_2 \cdot 6H_2O$	One point is earned for calculating the correct number of moles of anhydrous $MgCl_2$. One point is earned for writing the correct formula (with supporting calculations).

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Question 2 (continued)

(c) A different student heats the hydrate in an uncovered crucible, and some of the solid spatters out of the crucible. This spattering will have what effect on the calculated mass of the water lost by the hydrate? Justify your answer.

The calculated mass (or moles) of water lost by the hydrate will be too large because the mass of the solid that was lost will be assumed to be water when it actually included some $MgCl_2$ as well.	One point is earned for the correct answer with justification.

In the second experiment, a student is given 2.94 g of a mixture containing anhydrous $MgCl_2$ and KNO_3. To determine the percentage by mass of $MgCl_2$ in the mixture, the student uses excess $AgNO_3(aq)$ to precipitate the chloride ion as $AgCl(s)$.

(d) Starting with the 2.94 g sample of the mixture dissolved in water, briefly describe the steps necessary to quantitatively determine the mass of the AgCl precipitate.

Add excess $AgNO_3$. - Separate the AgCl precipitate (by filtration). - Wash the precipitate and dry the precipitate completely. - Determine the mass of AgCl by difference.	~~Two points are earned for all three major~~ steps: filtering the mixture, drying the precipitate, and determining the mass by difference. One point is earned for any two steps.

(e) The student determines the mass of the AgCl precipitate to be 5.48 g. On the basis of this information, calculate each of the following.

(i) The number of moles of $MgCl_2$ in the original mixture

$5.48 \text{ g AgCl} \times \frac{1 \text{ mol AgCl}}{143.32 \text{ g AgCl}} = 0.0382 \text{ mol AgCl}$ $0.0382 \text{ mol AgCl} \times \frac{1 \text{ mol Cl}}{1 \text{ mol AgCl}} \times \frac{1 \text{ mol } MgCl_2}{2 \text{ mol Cl}} = 0.0191 \text{ mol } MgCl_2$	One point is earned for calculating the number of moles of AgCl. One point is earned for conversion to moles of $MgCl_2$.

(ii) The percent by mass of $MgCl_2$ in the original mixture

$0.0191 \text{ mol } MgCl_2 \times \frac{95.20 \text{ g } MgCl_2}{1 \text{ mol } MgCl_2} = 1.82 \text{ g } MgCl_2$ $\frac{1.82 \text{ g } MgCl_2}{2.94 \text{ g sample}} \times 100\% = 61.9\% \text{ } MgCl_2 \text{ by mass}$	One point is earned for calculating the correct percentage.

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Question 2

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 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, 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 M HNO_3.

moles before dilution = moles after dilution $M_iV_i = M_fV_f$ $(16\ M)(V_i) = (6\ M)(50.\ mL)$ V_i = 19 mL or 20 mL (to one significant figure)	1 point is earned for the correct volume.

(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.

Wear safety goggles and rubber gloves. Then measure 19 mL of 16 M HNO_3 using a 100 mL graduated cylinder. Measure 31 mL of distilled H_2O using a 100 mL graduated cylinder. Transfer the water to a 100 mL beaker. Add the acid to the water with stirring.	1 point is earned for properly measuring the volume of 16 M HNO_3 and preparing a 6 M HNO_3 acid solution. 1 point is earned for wearing protective gear and for adding acid to water.

(iii) Explain why it is <u>not</u> necessary to use a volumetric flask (calibrated to 50.00 mL ±0.05 mL) to perform the dilution.

The graduated cylinders provide sufficient precision in volume measurement to provide two significant figures, making the use of the volumetric flask unnecessary.	1 point is earned for an acceptable explanation.

(iv) During the preparation of the solution, the student accidentally 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.

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Question 2 (continued)

$NaHCO_3(aq)$ should be used. The HCO_3^- ion will react as a base to neutralize the HNO_3.	1 point is earned for the correct choice with explanation.

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. After the sample completely reacts with the acid, some saturated NaCl(aq) 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, washed, 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 (first weighing)	29.3587 g
Mass of filter crucible and precipitate (second weighing)	29.2599 g
Mass of filter crucible and precipitate (third weighing)	29.2598 g

(b) Calculate the number of moles of AgCl precipitate collected.

mass of AgCl collected $= (29.2598 - 28.7210)\text{ g} = 0.5388\text{ g}$ $\frac{0.5388\text{ g}}{(107.87 + 35.45)\text{ g mol}^{-1}} = 3.759 \times 10^{-3}\text{ mol AgCl}$	1 point is earned for the correct mass of AgCl. 1 point is earned for the correct number of moles of AgCl given with the correct number of significant figures.

(c) Calculate the mass percent of silver in the alloy of copper and silver.

$3.759 \times 10^{-3}\text{ mol Ag} \times \frac{107.87\text{ g Ag}}{1\text{ mol Ag}} = 0.4055\text{ g Ag}$ $\frac{0.4055\text{ g}}{0.6489\text{ g}} \times 100\% = 62.49\%\text{ Ag}$	1 point is earned for the correct setup and the correct calculation of the mass of Ag. 1 point is earned for the correct percent of Ag.

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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.

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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.

$5.12 \times 10^{-4}\text{ mol } PbI_2 \times \frac{2\text{ mol } I^-}{1\text{ mol } PbI_2} = 1.02 \times 10^{-3}\text{ mol } I^-$ $1.02 \times 10^{-3}\text{ mol } I^- \times \frac{126.91\text{ g } I^-}{1\text{ mol } I^-} = 0.130\text{ g } I^-\text{ in one tablet}$ $\frac{0.130\text{ g } I^-}{0.425\text{ g KI tablet}} = 0.306 = 30.6\%\ I^-\text{ per KI tablet}$	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.

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Question 5

$$5\ Fe^{2+}(aq) + MnO_4^-(aq) + 8\ H^+(aq) \rightarrow 5\ Fe^{3+}(aq) + Mn^{2+}(aq) + 4\ H_2O(l)$$

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	One point is earned for the correct oxidation number.

(b) Identify the reducing agent in the reaction represented above.

$Fe^{2+}(aq)$	One point is earned for the correct iron ion.

The mass of a sample of the iron(II) compound is carefully measured before the sample is dissolved in distilled water. The resulting solution is acidified with $H_2SO_4(aq)$. The solution is then titrated with $MnO_4^-(aq)$ until the end point is reached.

(c) Describe the color change that occurs in the flask when the end point of the titration has been reached. Explain why the color of the solution changes at the end point.

The solution in the flask changes from colorless to faint purple-pink at the endpoint of the titration. At the endpoint there is no $Fe^{2+}(aq)$ left in the flask to reduce the colored permanganate ion, so when a small amount of permanganate ion is added after the endpoint, the unreacted permanganate ion present in the solution colors the solution faint purple/pink.	One point is earned for stating that a faint pink color appears (unless indication of acid-base reaction). One point is earned for a correct explanation involving excess MnO_4^- after all Fe^{2+} has reacted.

(d) Let the variables g, M, and V be defined as follows:

g = the mass, in grams, of the sample of the iron(II) compound

M = the molarity of the $MnO_4^-(aq)$ used as the titrant

V = the volume, in liters, of $MnO_4^-(aq)$ added to reach the end point

In terms of these variables, the number of moles of $MnO_4^-(aq)$ added to reach the end point of the titration is expressed as $M \times V$. Using the variables defined above, the molar mass of iron (55.85 g mol^{-1}), and the coefficients in the balanced chemical equation, write the expression for each of the following quantities.

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Question 5 (continued)

(i) The number of moles of iron in the sample

$\text{mol } Fe^{2+} = 5 \times M \times V$ **OR** $\text{mol } Fe^{2+} = \frac{5 \text{ mol } Fe^{2+}}{1 \text{ mol } MnO_4^-} \times M \times V$	One point is earned for either expression.

(ii) The mass of iron in the sample, in grams

$\text{mass Fe} = 5 \times M \times V \times 55.85 \text{ g mol}^{-1}$ **OR** $\text{mass Fe} = \text{mol } Fe^{2+} \times 55.85 \text{ g mol}^{-1}$	One point is earned for the answer in part (d)(i) multiplied by 55.85.

(iii) The mass percent of iron in the compound

$\text{mass \% Fe} = \frac{5 \times M \times V \times 55.85}{g} \times 100$ **OR** $\text{mass \% Fe} = \frac{\text{mass Fe}}{g} \times 100$	One point is earned for the answer in part (d)(ii) divided by g. One point is earned for converting to percent.

(e) What effect will adding too much titrant have on the experimentally determined value of the mass percent of iron in the compound? Justify your answer.

The experimentally determined mass percent of iron in the compound will be too large. V is too large $\Rightarrow$ expression in (d)(iii) above is too large	One point is earned for stating that the mass percent is too large, with justification.

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Question 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 precipitate forms with an appearance that is different from that of the dissolving solid.	One point is earned for stating that a precipitate is formed.

(b) Calculate the number of moles of each reactant.

$\text{mol } Pb(NO_3)_2 = 0.150 \text{ g } Pb(NO_3)_2 \times \frac{1 \text{ mol } Pb(NO_3)_2}{331 \text{ g } Pb(NO_3)_2}$ $= 4.53 \times 10^{-4} \text{ mol}$ $\text{mol NaI} = 0.100\,M \times 0.125 \text{ L} = 1.25 \times 10^{-2} \text{ mol}$	One point is earned for the correct number of moles of $Pb(NO_3)_2$. One point is earned for the correct number of moles of NaI.

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

$\text{mol NaI reacting} = 4.53 \times 10^{-4} \text{ mol } Pb(NO_3)_2 \times \frac{2 \text{ mol NaI}}{1 \text{ mol } Pb(NO_3)_2}$ $= 9.06 \times 10^{-4} \text{ mol}$ There is 1.25×10^{-2} mol of NaI initially, thus $Pb(NO_3)_2$ is the limiting reactant.	One point is earned for the identification of $Pb(NO_3)_2$. One point is earned for a justification in terms of the relative numbers of moles.

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

$[NO_3^-]_f = \frac{2 \times (4.53 \times 10^{-4} \text{ mol})}{0.125 \text{ L}} = 7.25 \times 10^{-3}\,M$	One point is earned for the correct NO_3^-/Pb^{2+} stoichiometry. One point is earned for the correct molarity.

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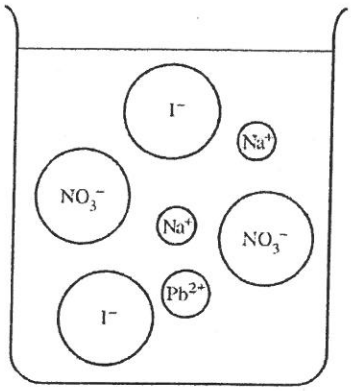
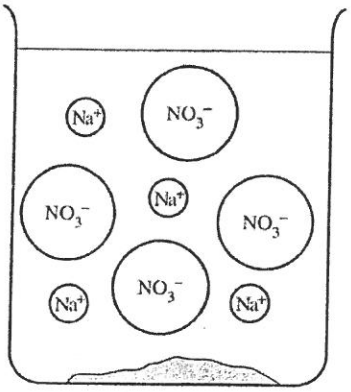
Question 3 (continued)

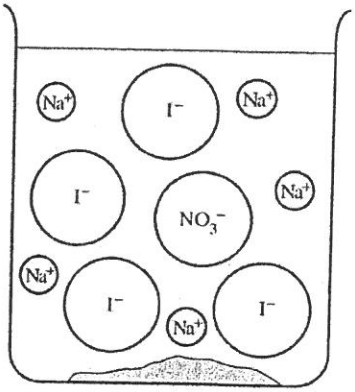
(e) Circle the diagram below that best represents the results after the mixture reacts as completely as possible. Explain the reasoning used in making your choice.



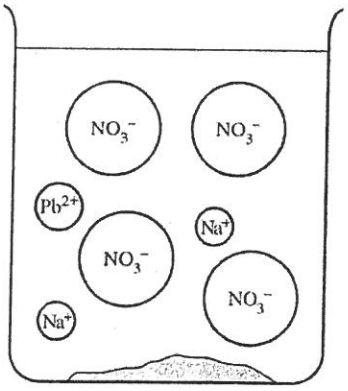
No Precipitate



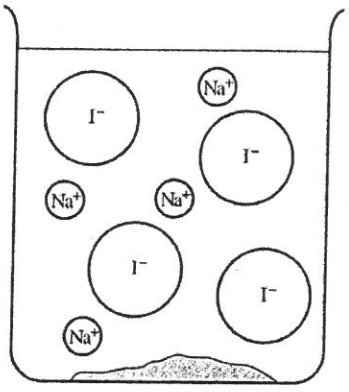
Solid PbI_2



Solid PbI_2



Solid PbI_2



Solid $Pb(NO_3)_2$

The rightmost diagram in the top row should be circled. PbI_2 precipitates and $Pb(NO_3)_2$ is the limiting reactant, so there is essentially no Pb^{2+} in solution. Because there was so much NaI in excess, some of the I^- remains in solution, along with the Na^+ and NO_3^-.	One point is earned for the selection of the correct diagram. One point is earned for the correct rationale.

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