

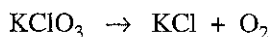
AP<sup>®</sup> CHEMISTRY  
2006 SCORING GUIDELINES

Question 4

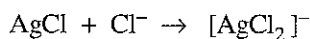
4. Write the formulas to show the reactants and the products for any FIVE of the laboratory situations described below. Answers to more than five choices will not be graded. In all cases, a reaction occurs. Assume that solutions are aqueous unless otherwise indicated. Represent substances in solution as ions if the substances are extensively ionized. Omit formulas for any ions or molecules that are unchanged by the reaction. You need not balance the equations.

General Scoring: Three points are earned for each reaction: 1 point for correct reactant(s) and 2 points for correct product(s). Designation of physical states is not required.

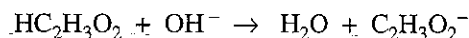
- (a) Solid potassium chlorate is strongly heated.



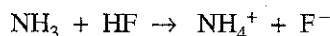
- (b) Solid silver chloride is added to a solution of concentrated hydrochloric acid.



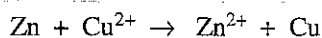
- (c) A solution of ethanoic (acetic) acid is added to a solution of barium hydroxide.



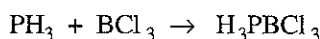
- (d) Ammonia gas is bubbled into a solution of hydrofluoric acid.



- (e) Zinc metal is placed in a solution of copper(II) sulfate.

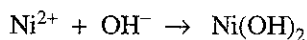


- (f) Hydrogen phosphide (phosphine) gas is added to boron trichloride gas.

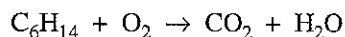


Note:  $\text{PH}_3\text{BCl}_3$  also acceptable as a product.

- (g) A solution of nickel(II) bromide is added to a solution of potassium hydroxide.



- (h) Hexane is combusted in air.



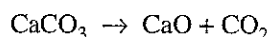
**AP<sup>®</sup> CHEMISTRY**  
**2006 SCORING GUIDELINES (Form B)**

**Question 4**

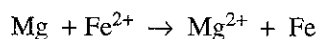
4. Write the formulas to show the reactants and the products for any FIVE of the laboratory situations described below. Answers to more than five choices will not be graded. In all cases, a reaction occurs. Assume that solutions are aqueous unless otherwise indicated. Represent substances in solution as ions if the substances are extensively ionized. Omit formulas for any ions or molecules that are unchanged by the reaction. You need not balance the equations.

General Scoring: Three points can be earned for each reaction: one point for the correct reactant(s) and two points for the correct product(s).

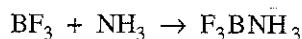
- (a) Solid calcium carbonate is strongly heated.



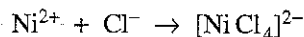
- (b) A strip of magnesium metal is placed in a solution of iron(II) chloride.



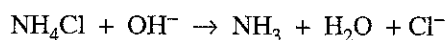
- (c) Boron trifluoride gas is mixed with ammonia gas.



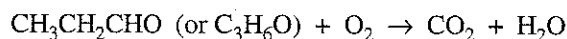
- (d) Excess concentrated hydrochloric acid is added to a solution of nickel(II) nitrate.



- (e) Solid ammonium chloride is added to a solution of potassium hydroxide.



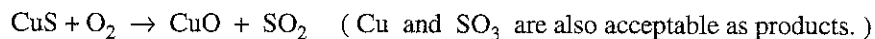
- (f) Propanal is burned in air.



- (g) A strip of aluminum foil is placed in liquid bromine.



- (h) Solid copper(II) sulfide is strongly heated in air.



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2007 SCORING GUIDELINES

Question 4

4. For each of the following three reactions, in part (i) write a balanced equation for the reaction and in part (ii) answer the question about the reaction. In part (i), coefficients should be in terms of lowest whole numbers. Assume that solutions are aqueous unless otherwise indicated. Represent substances in solutions as ions if the substances are extensively ionized. Omit formulas for any ions or molecules that are unchanged by the reaction. You may use the empty space at the bottom of the next page for scratch work, but only equations that are written in the answer boxes provided will be graded.

(a) A solution of sodium hydroxide is added to a solution of lead(II) nitrate.

(i) Balanced equation: $2 \text{OH}^- + \text{Pb}^{2+} \rightarrow \text{Pb}(\text{OH})_2$	One point is earned for the correct reactants. Two points are earned for the correct product. One point is earned for balancing the equation for mass and charge.
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(ii) If 1.0 L volumes of 1.0 M solutions of sodium hydroxide and lead(II) nitrate are mixed together, how many moles of product(s) will be produced? Assume the reaction goes to completion.

A total of 0.5 mol of $\text{Pb}(\text{OH})_2$ will be produced.	One point is earned for the correct number of moles.
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(b) Excess nitric acid is added to solid calcium carbonate.

(i) Balanced equation: $2 \text{H}^+ + \text{CaCO}_3 \rightarrow \text{Ca}^{2+} + \text{H}_2\text{O} + \text{CO}_2$	One point is earned for the correct reactants. Two points are earned for all three of the correct products; one point is earned for any one or two of the three. One point is earned for balancing the equation for mass and charge.
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(ii) Briefly explain why statues made of marble (calcium carbonate) displayed outdoors in urban areas are deteriorating.

The $\text{H}^+$ ions in acid rain react with the marble statues and the soluble compounds of Ca that are formed wash away.	One point is earned for a correct answer involving acid precipitation.
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2007 SCORING GUIDELINES

Question 4 (continued)

- (c) A solution containing silver(I) ion (an oxidizing agent) is mixed with a solution containing iron(II) ion (a reducing agent).

<p>(i) Balanced equation:</p> $\text{Ag}^+ + \text{Fe}^{2+} \rightarrow \text{Ag} + \text{Fe}^{3+}$	<p>One point is earned for the correct reactants.</p> <p>One point is earned for each of the two correct products.</p> <p>One point is earned for balancing the equation for mass and charge.</p>
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- (ii) If the contents of the reaction mixture described above are filtered, what substance(s), if any, would remain on the filter paper?

<p>The precipitated solid silver will remain on the filter paper.</p>	<p>One point is earned for the correct substance.</p>
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**AP<sup>®</sup> CHEMISTRY**  
**2007 SCORING GUIDELINES (Form B)**

**Question 4**

For each of the following three reactions, in part (i) write a balanced equation for the reaction and in part (ii) answer the question about the reaction. In part (i), coefficients should be in terms of lowest whole numbers. Assume that solutions are aqueous unless otherwise indicated. Represent substances in solutions as ions if the substances are extensively ionized. Omit formulas for any ions or molecules that are unchanged by the reaction. You may use the empty space at the bottom of the next page for scratch work, but only equations that are written in the answer boxes provided will be graded.

(a) Solid ammonium carbonate decomposes as it is heated.

(i) Balanced equation: $(\text{NH}_4)_2\text{CO}_3 \rightarrow 2 \text{NH}_3 + \text{CO}_2 + \text{H}_2\text{O}$	One point is earned for the correct reactant. Two points are earned for correct products. One point is earned for balancing mass and charge.
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(ii) Predict the algebraic sign of  $\Delta S^\circ$  for the reaction. Explain your reasoning.

The algebraic sign of $\Delta S^\circ$ for the reaction will be positive because one mole of solid (with relatively low entropy) is converted into four moles of gas (with much greater entropy).	One point is earned for the correct answer.
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(b) Chlorine gas, an oxidizing agent, is bubbled into a solution of potassium bromide.

(i) Balanced equation: $\text{Cl}_2 + 2 \text{Br}^- \rightarrow 2 \text{Cl}^- + \text{Br}_2$	One point is earned for correct reactants. Two points are earned for correct products. One point is earned for balancing mass and charge.
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(ii) What is the oxidation number of chlorine before the reaction occurs? What is the oxidation number of chlorine after the reaction occurs?

The oxidation number of chlorine is 0 before the reaction and -1 after the reaction.	One point is earned for the correct answer.
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(c) A small piece of sodium is placed in a beaker of distilled water.

(i) Balanced equation: $2 \text{Na} + 2 \text{H}_2\text{O} \rightarrow \text{H}_2 + 2 \text{Na}^+ + 2 \text{OH}^-$	One point is earned for correct reactants. Two points are earned for correct products. One point is earned for balancing mass and charge.
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(ii) The reaction is exothermic, and sometimes small flames are observed as the sodium reacts with the water. Identify the product of the reaction that burns to produce the flames.

It is the $\text{H}_2$ gas that burns.	One point is earned for the correct answer.
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2008 SCORING GUIDELINES

Question 4

- (a) Aqueous sodium hydroxide is added to a saturated solution of aluminum hydroxide, forming a complex ion.

<p>(i) Balanced equation:</p> $\text{Al(OH)}_3 + \text{OH}^- \rightarrow [\text{Al(OH)}_4]^-$ $\text{Al(OH)}_3 + 3 \text{OH}^- \rightarrow [\text{Al(OH)}_6]^{3-}$ $\text{Al}^{3+} + 4 \text{OH}^- \rightarrow [\text{Al(OH)}_4]^-$ $\text{Al}^{3+} + 6 \text{OH}^- \rightarrow [\text{Al(OH)}_6]^{3-}$	<p>One point is earned for the correct reactants.</p> <p>Two points are earned for a correct product.</p> <p>One point is earned for balancing the equation.</p>
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- (ii) If the resulting mixture is acidified, would the concentration of the complex ion increase, decrease, or remain the same? Explain.

<p>The <math>[\text{Al(OH)}_4]^-</math> will decrease because ...</p> <p>(If equilibrium exists), the <math>\text{H}^+</math> added would react with the <math>\text{OH}^-</math> in solution, reducing the <math>[\text{OH}^-]</math> and shifting the equilibrium toward the reactants, thus reducing the concentration of the complex ion.</p> <p>OR</p> <p>(If the reaction has gone to completion), the <math>\text{H}^+</math> added would react with the <math>[\text{Al(OH)}_4]^-</math>, thus reducing the concentration.</p> $[\text{Al(OH)}_4]^- + \text{H}^+ \rightarrow \text{Al(OH)}_3 + \text{H}_2\text{O}$	<p>One point is earned for a correct answer with an explanation.</p>
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**2008 SCORING GUIDELINES**

**Question 4 (continued)**

(b) Hydrogen chloride gas is oxidized by oxygen gas.

<p>(i) Balanced equation</p> $4 \text{HCl} + \text{O}_2 \rightarrow 2 \text{H}_2\text{O} + 2 \text{Cl}_2$ <p>Some other acceptable equations and products:</p> $4 \text{HCl} + 3 \text{O}_2 \rightarrow 2 \text{H}_2\text{O} + 4 \text{ClO}$ $4 \text{HCl} + 5 \text{O}_2 \rightarrow 2 \text{H}_2\text{O} + 4 \text{ClO}_2$ $4 \text{HCl} + 7 \text{O}_2 \rightarrow 2 \text{H}_2\text{O} + 4 \text{ClO}_3$ $2 \text{HCl} + \text{O}_2 \rightarrow 2 \text{HClO}$ $\text{HCl} + \text{O}_2 \rightarrow \text{HClO}_2$ $2 \text{HCl} + 3 \text{O}_2 \rightarrow 2 \text{HClO}_3$ $\text{HCl} + 2 \text{O}_2 \rightarrow \text{HClO}_4$	<p>One point is earned for the correct reactants.</p> <p>Two points are earned for the correct products.</p> <p>One point is earned for balancing the equation.</p>
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(ii) If three moles of hydrogen chloride gas and three moles of oxygen gas react as completely as possible, which reactant, if any, is present in excess? Justify your answer.

<p><math>\text{O}_2</math> would be in excess because of the stoichiometry of the reaction; 4 moles of HCl are consumed for 1 mole of <math>\text{O}_2</math>. (It takes only 0.75 mole of <math>\text{O}_2</math> to react with 3 moles of HCl, leaving an excess of 2.25 moles of <math>\text{O}_2</math>.)</p> <p>For other acceptable equations and products, the excess reactant must be based on the stoichiometry of the reaction given by the student.</p>	<p>One point is earned for a correct answer that is based on the balanced chemical equation and that has an appropriate justification.</p>
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**2008 SCORING GUIDELINES**

**Question 4 (continued)**

(c) Solid potassium oxide is added to water.

<p>(i) Balanced equation:</p> $\text{K}_2\text{O} + \text{H}_2\text{O} \rightarrow 2 \text{K}^+ + 2 \text{OH}^-$	<p>One point is earned for the correct reactants.</p> <p>Two points are earned for the correct products.</p> <p>One point is earned for balancing the equation.</p>
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(ii) If a few drops of phenolphthalein are added to the resulting solution, what would be observed? Explain.

<p>The solution would turn pink because the production of <math>\text{OH}^-</math> makes the solution basic. In basic solutions, phenolphthalein turns pink.</p>	<p>One point is earned for the correct answer with an explanation.</p>
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**AP<sup>®</sup> CHEMISTRY**  
**2008 SCORING GUIDELINES (Form B)**

**Question 4**

For each of the following three reactions, in part (i) write a balanced equation for the reaction and in part (ii) answer the question about the reaction. In part (i), coefficients should be in terms of lowest whole numbers. Assume that solutions are aqueous unless otherwise indicated. Represent substances in solutions as ions if the substances are extensively ionized. Omit formulas for any ions or molecules that are unchanged by the reaction. You may use the empty space at the bottom of the next page for scratch work, but only equations that are written in the answer boxes provided will be graded.

- (a) Chlorine gas, an oxidizing agent, is bubbled into a solution of potassium bromide at 25°C.

<p>(i) Balanced equation:</p> $\text{Cl}_2 + 2 \text{Br}^- \rightarrow 2 \text{Cl}^- + \text{Br}_2$	<p>One point is earned for the correct reactants.</p> <p>Two points are earned for the correct products.</p> <p>One point is earned for balancing the equation for mass and charge.</p>
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- (ii) Predict the sign of  $\Delta S^\circ$  for the reaction at 25°C. Justify your prediction.

<p>The sign of <math>\Delta S^\circ</math> is negative. One of the reactants, <math>\text{Cl}_2</math>, is a gas at 25°C, but there are no gaseous products. Gases have high entropies, so the entropy of the reactants is greater than the entropy of the products, making <math>\Delta S^\circ</math> negative.</p>	<p>One point is earned for a correct answer involving entropy of a gas.</p>
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- (b) Solid strontium hydroxide is added to a solution of nitric acid.

<p>(i) Balanced equation:</p> $\text{Sr}(\text{OH})_2 + 2 \text{H}^+ \rightarrow \text{Sr}^{2+} + 2 \text{H}_2\text{O}$	<p>One point is earned for the correct reactants.</p> <p>Two points are earned for the correct products.</p> <p>One point is earned for balancing the equation for mass and charge.</p>
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- (ii) How many moles of strontium hydroxide would react completely with 500. mL of 0.40 M nitric acid?

<p>There is 0.20 mol of <math>\text{H}^+</math> in 500. mL of 0.40 M nitric acid. Because there are two moles of <math>\text{OH}^-</math> in each mole of <math>\text{Sr}(\text{OH})_2</math>, 0.10 mol of <math>\text{Sr}(\text{OH})_2</math> is needed to react completely.</p>	<p>One point is earned for the correct answer.</p>
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**2008 SCORING GUIDELINES (Form B)**

**Question 4 (continued)**

- (c) A solution of barium chloride is added drop by drop to a solution of sodium carbonate, causing a precipitate to form.

<p>(i) Balanced equation:</p> $\text{Ba}^{2+} + \text{CO}_3^{2-} \rightarrow \text{BaCO}_3$	<p>One point is earned for the correct reactants.</p> <p>Two points are earned for the correct product.</p> <p>One point is earned for balancing the equation for mass and charge.</p>
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- (ii) What happens to the pH of the sodium carbonate solution as the barium chloride is added to it?

<p>A solution of sodium carbonate is basic. When carbonate precipitates out, this decreases the pH.</p>	<p>One point is earned for the correct answer (no explanation is required).</p>
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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.

<p>(i) Balanced equation:</p> $2 \text{Fe}_2\text{O}_3 + 3 \text{C} \rightarrow 4 \text{Fe} + 3 \text{CO}_2$ <p style="text-align: center;"><b>OR</b></p> $\text{Fe}_2\text{O}_3 + 3 \text{C} \rightarrow 2 \text{Fe} + 3 \text{CO}$	<p>One point is earned for both correct reactants.</p> <p>Two points are earned for the correct products (1 point each).</p> <p>One point is earned for correctly balancing (mass and charge) the equation.</p>
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(ii) What is the oxidation number of carbon before the reaction, and what is the oxidation number of carbon after the reaction is complete?

<p>The oxidation number of C before the reaction is 0, and the oxidation number of C after the reaction is +4.</p>	<p>One point is earned for both oxidation numbers consistent with part (i).</p>
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(b) Equal volumes of equimolar solutions of ammonia and hydrochloric acid are combined.

<p>(i) Balanced equation:</p> $\text{NH}_3 + \text{H}^+ \rightarrow \text{NH}_4^+$ <p style="text-align: center;"><b>OR</b></p> $\text{NH}_3 + \text{H}_3\text{O}^+ \rightarrow \text{NH}_4^+ + \text{H}_2\text{O}$	<p>Two points are earned for the correct reactants.</p> <p>One point is earned for the correct product(s).</p> <p>One point is earned for correctly balancing (mass and charge) the equation.</p>
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(ii) Indicate whether the resulting solution is acidic, basic, or neutral. Explain.

<p>The resulting solution is acidic because of the hydrolysis of the <math>\text{NH}_4^+</math> ion, which reacts with water to form <math>\text{NH}_3</math> and <math>\text{H}^+</math>.</p> <p style="text-align: center;"><b>OR</b></p> <p>The mixing of a strong acid and a weak base results in an acidic solution.</p>	<p>One point is earned for a correct answer consistent with part (i).</p>
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**2009 SCORING GUIDELINES**

**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:  $2 \text{HgO} \rightarrow 2 \text{Hg} + \text{O}_2$	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.
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(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 <sub>2</sub> gas to the atmosphere.	One point is earned for a correct answer consistent with part (i).
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**AP<sup>®</sup> CHEMISTRY**  
**2009 SCORING GUIDELINES (Form B)**

**Question 4 (15 points)**

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

<p>(i) Balanced equation:</p> $\text{Ba}^{2+} + 2 \text{F}^{-} \rightarrow \text{BaF}_2$	<p>Two points are earned for the correct reactants (1 point each).</p> <p>One point is earned for the correct product.</p> <p>One point is earned for correctly balancing the equation for atoms and charge.</p>
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- (ii) If equimolar amounts of barium nitrate and potassium fluoride are combined, which reactant, if any, is the limiting reactant? Explain.

<p>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.</p>	<p>One point is earned for a correct answer that is consistent with part (i).</p>
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- (b) A piece of cadmium metal is oxidized by adding it to a solution of copper(II) chloride.

<p>(i) Balanced equation:</p> $\text{Cd} + \text{Cu}^{2+} \rightarrow \text{Cd}^{2+} + \text{Cu}$	<p>One point is earned for <u>both</u> correct reactants.</p> <p>One point is earned for <u>both</u> correct products.</p> <p>One point is earned for correctly balancing the equation for atoms and charge.</p>
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- (ii) List two visible changes that would occur in the reaction container as the reaction is proceeding.

<p>In the solution, the blue color of the copper(II) cation would decrease, and eventually the solution would become colorless.</p> <p>Reddish-brown (or black) copper metal would plate out onto the piece of silvery cadmium metal.</p>	<p>Two points are earned for correctly describing the changes (1 point each).</p>
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**2009 SCORING GUIDELINES (Form B)**

**Question 4 (continued)**

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

<p>(i) Balanced equation:</p> $\text{Na}_2\text{S} + \text{H}_2\text{O} \rightarrow 2 \text{Na}^+ + \text{HS}^- + \text{OH}^-$ <p style="text-align: center;"><b>OR</b></p> $\text{Na}_2\text{S} + 2 \text{H}_2\text{O} \rightarrow 2 \text{Na}^+ + \text{H}_2\text{S} + 2 \text{OH}^-$	<p>One point is earned for <u>both</u> correct reactants.</p> <p>One point is earned for any <u>two</u> correct products; 2 points are earned for all <u>three</u> correct products.</p> <p>One point is earned for correctly balancing the equation for atoms and charge.</p>
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(ii) Indicate whether the pH of the resulting solution is less than 7, equal to 7, or greater than 7. Explain.

<p>The pH of the resulting solution is greater than 7. The hydrolysis reaction of <math>\text{S}^{2-}</math> produces the base <math>\text{OH}^-</math>, thus raising the pH above 7.</p>	<p>One point is earned for a correct answer that is consistent with part (i).</p>
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**2010 SCORING GUIDELINES**

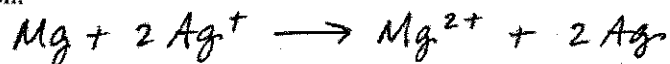
**Question 4**  
**(15 points)**

For each of the following three reactions, write a balanced equation for the reaction in part (i) and answer the question about the reaction in part (ii). In part (i), coefficients should be in terms of lowest whole numbers. Assume that solutions are aqueous unless otherwise indicated. Represent substances in solutions as ions if the substances are extensively ionized. Omit formulas for any ions or molecules that are unchanged by the reaction. You may use the empty space at the bottom of the next page for scratch work, but only equations that are written in the answer boxes provided will be scored.

**EXAMPLE:**

A strip of magnesium metal is added to a solution of silver(I) nitrate.

(i) Balanced equation:

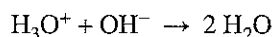


(ii) Which substance is oxidized in the reaction?

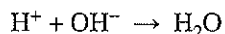
*Mg is oxidized.*

(a) A 0.2 M potassium hydroxide solution is titrated with a 0.1 M nitric acid solution.

(i) Balanced equation:



*OR*



One point is earned for each correct reactant.

One point is earned for the correct product.

One point is earned for correctly balancing (mass and charge) the equation.

(ii) What would be observed if the solution was titrated well past the equivalence point using bromthymol blue as the indicator? (Bromthymol blue is yellow in acidic solution and blue in basic solution.)

The solution would appear yellow.

One point is earned for the correct description of the solution.

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**2010 SCORING GUIDELINES**

**Question 4 (continued)**

(b) Propane is burned completely in excess oxygen gas.

(i) Balanced equation: $\text{C}_3\text{H}_8 + 5 \text{O}_2 \rightarrow 3 \text{CO}_2 + 4 \text{H}_2\text{O}$	One point is earned for both correct reactants. Two points are earned for the correct products. One point is earned for correctly balancing the equation.
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(ii) When the products of the reaction are bubbled through distilled water, is the resulting solution neutral, acidic, or basic? Explain.

The resulting solution would be acidic because $\text{CO}_2$ reacts with water as a weak acid.	One point is earned for the correct choice with justification.
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(c) A solution of hydrogen peroxide is heated, and a gas is produced.

(i) Balanced equation: $2 \text{H}_2\text{O}_2 \rightarrow 2 \text{H}_2\text{O} + \text{O}_2$	One point is earned for the correct reactant. Two points are earned for the correct products. One point is earned for correctly balancing the equation.
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(ii) Identify the oxidation state of oxygen in hydrogen peroxide.

The oxidation state of O in $\text{H}_2\text{O}_2$ is $-1$ .	One point is earned for the correct oxidation state.
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**AP<sup>®</sup> CHEMISTRY**  
**2010 SCORING GUIDELINES (Form B)**

**Question 4**  
**(15 points)**

(a) Solid copper(II) sulfate pentahydrate is gently heated.

<p>(i) Balanced equation:</p> $\text{CuSO}_4 \cdot 5\text{H}_2\text{O} \rightarrow \text{CuSO}_4 + 5 \text{H}_2\text{O}$	<p>One point is earned for the reactant.                  Two points are earned for products.                  One point is earned for balancing the equation.</p>
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(ii) How many grams of water are present in 1.00 mol of copper(II) sulfate pentahydrate?

$1.00 \text{ mol CuSO}_4 \cdot 5\text{H}_2\text{O} \times \frac{5 \text{ mol H}_2\text{O}}{1.00 \text{ mol CuSO}_4 \cdot 5\text{H}_2\text{O}} \times \frac{18.0 \text{ g H}_2\text{O}}{1.00 \text{ mol H}_2\text{O}}$ $= 90.0 \text{ g H}_2\text{O}$	<p>One point is earned for the correct numerical answer.</p>
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(b) Excess concentrated aqueous ammonia is added to a solution of nickel(II) nitrate, leading to the formation of a complex ion.

<p>(i) Balanced equation:</p> $\text{Ni}^{2+} + 6 \text{NH}_3 \rightarrow [\text{Ni}(\text{NH}_3)_6]^{2+}$	<p>Two points are earned for reactants.                  One point is earned for the product.                  One point is earned for balancing (mass and charge) the equation.</p>
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(ii) Which of the reactants acts as a Lewis acid?

$\text{Ni}^{2+}$	<p>One point is earned for correct identification of the Lewis acid.</p>
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(c) Methylamine ( $\text{CH}_3\text{NH}_2$ ) is added to a solution of hydrochloric acid.

<p>(i) Balanced equation:</p> $\text{CH}_3\text{NH}_2 + \text{H}^+ \rightarrow \text{CH}_3\text{NH}_3^+$ <p style="text-align: center;"><i>OR</i></p> $\text{CH}_3\text{NH}_2 + \text{H}_3\text{O}^+ \rightarrow \text{CH}_3\text{NH}_3^+ + \text{H}_2\text{O}$	<p>Two points are earned for reactants.                  One point is earned for the product.                  One point is earned for balancing (mass and charge) the equation.</p>
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(ii) Methylamine dissolves in water to form a solution. Indicate whether this solution is acidic, basic, or neutral.

<p>The solution would be basic (because it would react with water to form <math>\text{CH}_3\text{NH}_3^+</math> ions and <math>\text{OH}^-</math> ions).</p>	<p>One point is earned for the correct choice.</p>
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**AP<sup>®</sup> CHEMISTRY**  
**2011 SCORING GUIDELINES**

**Question 4**

For each of the following three reactions, write a balanced equation for the reaction in part (i) and answer the question about the reaction in part (ii). In part (i), coefficients should be in terms of lowest whole numbers. Assume that solutions are aqueous unless otherwise indicated. Represent substances in solutions as ions if the substances are extensively ionized. Omit formulas for any ions or molecules that are unchanged by the reaction. You may use the empty space at the bottom of the next page for scratch work, but only equations that are written in the answer boxes provided will be scored.

(a) Solid magnesium hydroxide is added to a solution of hydrobromic acid.

<p>(i) <math>\text{Mg}(\text{OH})_2 + 2 \text{H}^+ \rightarrow \text{Mg}^{2+} + 2 \text{H}_2\text{O}</math></p>	<p>1 point is earned for the correct reactants.</p> <p>2 points are earned for the correct products.</p> <p>1 point is earned for correctly balancing the equation for both mass and charge.</p>
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(ii) What volume, in mL, of 2.00 M hydrobromic acid is required to react completely with 0.10 mol of solid magnesium hydroxide?

<p><math>\text{mol H}^+ \text{ or HBr} = 0.10 \text{ mol Mg}(\text{OH})_2 \times \frac{2 \text{ mol H}^+}{1 \text{ mol Mg}(\text{OH})_2} = 0.20 \text{ mol H}^+</math></p> <p><math>0.20 \text{ mol H}^+ \times \frac{1.00 \text{ L}}{2.00 \text{ mol H}^+} \times \frac{1,000 \text{ mL}}{1.00 \text{ L}} = 100 \text{ mL}</math></p>	<p>1 point is earned for the correct volume.</p>
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(b) Excess hydrochloric acid is added to a solution of cobalt(II) nitrate to produce a coordination complex.

<p>(i) <math>\text{Co}^{2+} + 4 \text{Cl}^- \rightarrow [\text{CoCl}_4]^{2-}</math></p> <p><u>Note:</u> any number of coordinated <math>\text{Cl}^-</math> ions from 1 to 6 is acceptable.</p>	<p>2 points are earned for the correct reactants.</p> <p>1 point is earned for the correct product.</p> <p>1 point is earned for correctly balancing the equation for both mass and charge.</p>
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(ii) Which species in the reaction acts as a Lewis base?

<p><math>\text{Cl}^-</math> functions as a Lewis base.</p>	<p>1 point is earned for the correct identification of the Lewis base.</p>
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2011 SCORING GUIDELINES

Question 4 (continued)

(c) A copper wire is dipped into a solution of silver(I) nitrate.

<p>(i) <math>\text{Cu} + 2 \text{Ag}^+ \rightarrow \text{Cu}^{2+} + 2 \text{Ag}</math></p>	<p>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 both mass and charge.</p>
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(ii) Describe what is observed as the reaction proceeds.

<p>Silver metal will appear on the surface of the copper wire. OR The solution will turn blue. OR The copper wire will lose mass.</p>	<p>1 point is earned for any one of the observations.</p>
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**AP<sup>®</sup> CHEMISTRY**  
**2011 SCORING GUIDELINES (Form B)**

**Question 4**  
**(15 points)**

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

Balanced equation: $\text{Zn} + 2\text{H}^+ \rightarrow \text{Zn}^{2+} + \text{H}_2$	1 point is earned for the correct reactants. 2 points are earned for the correct products. 1 point is earned for the balanced equation.
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(ii) Write the oxidation half-reaction for the reaction.

$\text{Zn} \rightarrow \text{Zn}^{2+} + 2e^-$	1 point is earned for the balanced half-reaction.
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(b) Solid lithium oxide is added to distilled water.

Balanced equation: $\text{Li}_2\text{O} + \text{H}_2\text{O} \rightarrow 2\text{Li}^+ + 2\text{OH}^-$	1 point is earned for the correct reactants. 2 points are earned for the correct products. 1 point is earned for the balanced equation.
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(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 $\text{OH}^-$ , a strong base, is formed in the reaction.	1 point is earned for the correct answer.
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(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: $\text{Sr}^{2+} + \text{CO}_3^{2-} \rightarrow \text{SrCO}_3$	2 points are earned for the correct reactants. 1 point is earned for the correct product. 1 point is earned for the balanced equation.
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(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 $\text{CO}_2$ form.	1 point is earned for a correct answer.
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**AP<sup>®</sup> CHEMISTRY**  
**2012 SCORING GUIDELINES**

**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: $2 \text{H}^+ + \text{SrCO}_3 \rightarrow \text{Sr}^{2+} + \text{CO}_2 + \text{H}_2\text{O}$ OR, $\text{H}^+ + \text{SrCO}_3 \rightarrow \text{Sr}^{2+} + \text{HCO}_3^-$	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.
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(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.
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(b) Magnesium metal is strongly heated in oxygen gas.

(i) Balanced equation: $2 \text{Mg} + \text{O}_2 \rightarrow 2 \text{MgO}$	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.
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(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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**AP<sup>®</sup> CHEMISTRY**  
**2012 SCORING GUIDELINES**

**Question 4 (continued)**

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

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

<p>The chloride ion</p>	<p>1 point is earned for the correct ion.</p>
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