

**AP<sup>®</sup> CHEMISTRY**  
**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><i>OR</i></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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**AP<sup>®</sup> CHEMISTRY**  
**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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**AP<sup>®</sup> CHEMISTRY**  
**2008 SCORING GUIDELINES**

**Question 4 (continued)**

(c) Solid potassium oxide is added to water.

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

The solution would turn pink because the production of $\text{OH}^-$ makes the solution basic. In basic solutions, phenolphthalein turns pink.	One point is earned for the correct answer with an explanation.
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4A1

CHEMISTRY

Part B

Time—40 minutes

NO CALCULATORS MAY BE USED FOR PART B.

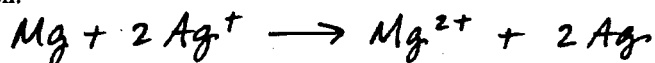
Answer Question 4 below. The Section II score weighting for this question is 10 percent.

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.

**EXAMPLE:**

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

(i) Balanced equation:

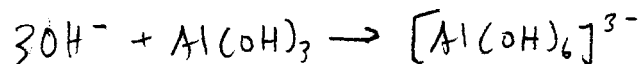


(ii) Which substance is oxidized in the reaction?

Mg is oxidized.

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

(i) Balanced equation:



(ii) If the resulting mixture is acidified, would the concentration of the complex ion increase, decrease, or remain the same? Explain.

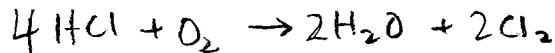
The concentration of complex ion will decrease. The acid will decrease the concentration of  $\text{OH}^-$ , so the reaction will shift to the left, and less complex ion is produced.

**B B B****B B B B B**

4A2

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

(i) Balanced equation:

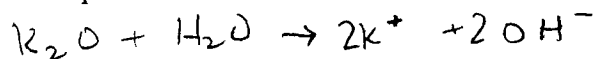


(ii) If three moles of hydrogen chloride gas and three moles of oxygen gas react as completely as possible, which reactant, if any, is present in excess? Justify your answer.

There will be excess  $\text{O}_2$ . To react 3 moles of  $\text{HCl}$  completely, only 0.75 moles  $\text{O}_2$  are needed. Since there are 3 moles of  $\text{O}_2$  present, there will be 2.25 moles in excess.

(c) Solid potassium oxide is added to water.

(i) Balanced equation:



(ii) If a few drops of phenolphthalein are added to the resulting solution, what would be observed? Explain.

If phenolphthalein is added, the solution will turn pink. Phenolphthalein turns pink in the presence of a base such as  $\text{KOH}$ .

**YOU MAY USE THE SPACE BELOW FOR SCRATCH WORK, BUT ONLY EQUATIONS THAT ARE WRITTEN IN THE ANSWER BOXES PROVIDED WILL BE GRADED.**

CHEMISTRY

Part B

Time—40 minutes

NO CALCULATORS MAY BE USED FOR PART B.

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

(i) Balanced equation:  

$$\text{Mg} + 2\text{Ag}^+ \rightarrow \text{Mg}^{2+} + 2\text{Ag}$$

(ii) Which substance is oxidized in the reaction?  
Mg is oxidized.

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

(i) Balanced equation:  

$$\text{Na}^+ + 4\text{OH}^- + \text{Al}^+ \rightarrow \text{NaAlO}_2 + 2\text{H}_2\text{O}$$

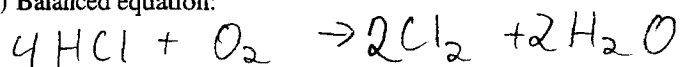
(ii) If the resulting mixture is acidified, would the concentration of the complex ion increase, decrease, or remain the same? Explain.  
Decrease the  $\text{H}^+$  would bond with  $\text{OH}^-$  ions shifting equilibrium to the reactants side

**B****B B B B B B B**

4B2

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

(i) Balanced equation:



(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.

O<sub>2</sub> gas when 1 mole of HCl is used  $\frac{1}{4}$  mole  
of O<sub>2</sub> is used therefore HCl will be the limiting  
reactant.

(c) Solid potassium oxide is added to water.

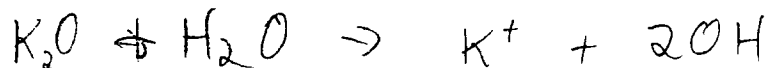
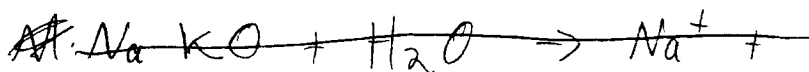
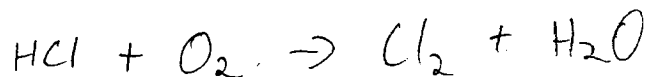
(i) Balanced equation:



(ii) If a few drops of phenolphthalein are added to the resulting solution, what would be observed? Explain.

It would turn pink because it is  
basic.

**YOU MAY USE THE SPACE BELOW FOR SCRATCH WORK, BUT ONLY EQUATIONS THAT ARE WRITTEN IN THE ANSWER BOXES PROVIDED WILL BE GRADED.**



CHEMISTRY

Part B

Time—40 minutes

NO CALCULATORS MAY BE USED FOR PART B.

Answer Question 4 below. The Section II score weighting for this question is 10 percent.

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.

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

(i) Balanced equation:  

$$\text{Mg} + 2\text{Ag}^+ \rightarrow \text{Mg}^{2+} + 2\text{Ag}$$

(ii) Which substance is oxidized in the reaction?  
Mg is oxidized.

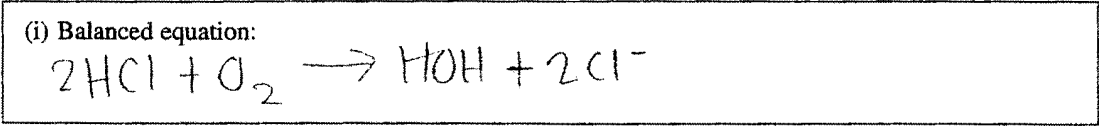
- (a) Aqueous sodium hydroxide is added to a saturated solution of aluminum hydroxide, forming a complex ion.

(i) Balanced equation:  

$$2\text{Al}(\text{OH})_3 \rightarrow 3\text{O}_2 + 2[\text{Al}(\text{H}_2\text{O})_6]^+$$

(ii) If the resulting mixture is acidified, would the concentration of the complex ion increase, decrease, or remain the same? Explain.  
The concentration would stay the same.

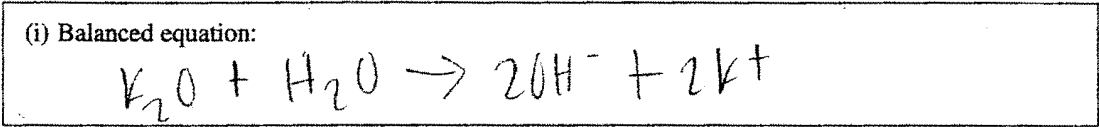
(b) Hydrogen chloride gas is oxidized by oxygen gas.



(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.

No reactant would be in excess because the hydrogen chloride gas would be completely oxidized.

(c) Solid potassium oxide is added to water.



(ii) If a few drops of phenolphthalein are added to the resulting solution, what would be observed? Explain.

The solution would turn pink because when metal oxides are placed in water they form basic solutions.

**YOU MAY USE THE SPACE BELOW FOR SCRATCH WORK, BUT ONLY EQUATIONS THAT ARE WRITTEN IN THE ANSWER BOXES PROVIDED WILL BE GRADED.**

**AP<sup>®</sup> CHEMISTRY**  
**2008 SCORING COMMENTARY**

**Question 4**

**Overview**

This question was intended to assess students' ability to write both molecular and net-ionic equations and to recognize when each is appropriate. Various aspects of the question were intended to reinforce knowledge gleaned from the classroom and from experience in the laboratory.

**Sample: 4A**

**Score: 15**

This response earned all 15 points: 4 for part (a)(i), 1 for part (a)(ii), 4 for part (b)(i), 1 for part (b)(ii), 4 for part (c)(i), and 1 for part (c)(ii).

**Sample: 4B**

**Score: 9**

No points were earned in part (a)(i).  $\text{Na}^+$  should not be included as a reactant, and the aluminum ion has an incorrect charge. No complex ion is shown as a product, and the equation is mass balanced but not charge balanced. The point was earned in part (a)(ii); this response shows understanding of the effect of removing hydroxide ions and so earned credit. All points were earned in parts (b)(i) and (b)(ii). In part (c)(i) 1 point was earned for the reactants, but only 1 of the 2 product points was earned because of the lack of a charge on  $\text{OH}$ . The balancing point was not earned; the equation is not balanced for mass or charge. The point was earned in part (c)(ii).

**Sample: 4C**

**Score: 7**

No points were earned in part (a)(i). The reactant point was not earned because  $\text{OH}^-$  is not included. The product points were not earned because no acceptable complex ion is given. The equation is not balanced for charge, so the balancing point was not earned. The point was not earned in part (a)(ii). In part (b)(i) the reactant point was earned. Only 1 of the 2 product points was earned;  $\text{HOH}$  ( $\text{H}_2\text{O}$ ) is an acceptable product, but  $\text{Cl}^-$  is not. The balancing point was not earned; neither mass nor charge is balanced. In part (b)(ii) the response is not consistent with the equation given in part (b)(i), so the point was not earned. All the points were earned in parts (c)(i) and (c)(ii).