

**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?

$\text{mol H}^+ \text{ or HBr} = 0.10 \text{ mol Mg}(\text{OH})_2 \times \frac{2 \text{ mol H}^+}{1 \text{ mol Mg}(\text{OH})_2} = 0.20 \text{ mol H}^+$ $0.20 \text{ mol H}^+ \times \frac{1.00 \text{ L}}{2.00 \text{ mol H}^+} \times \frac{1,000 \text{ mL}}{1.00 \text{ L}} = 100 \text{ mL}$	<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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**AP<sup>®</sup> CHEMISTRY**  
**2011 SCORING GUIDELINES**

**Question 4 (continued)**

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

(i) $\text{Cu} + 2 \text{Ag}^+ \rightarrow \text{Cu}^{2+} + 2 \text{Ag}$	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.
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(ii) Describe what is observed as the reaction proceeds.

Silver metal will appear on the surface of the copper wire. OR The solution will turn blue. OR The copper wire will lose mass.	1 point is earned for any one of the observations.
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CHEMISTRY

Part B

Time—40 minutes

NO CALCULATORS MAY BE USED FOR PART B.

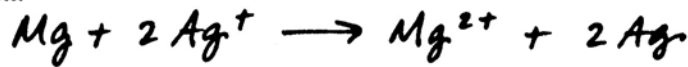
Answer Question 4 below. The Section II score weighting for this question is 10 percent.

4. For each of the following three reactions, 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:

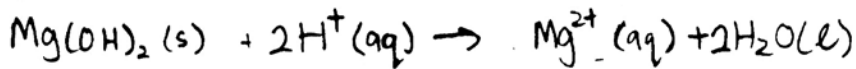


(ii) Which substance is oxidized in the reaction?

Mg is oxidized.

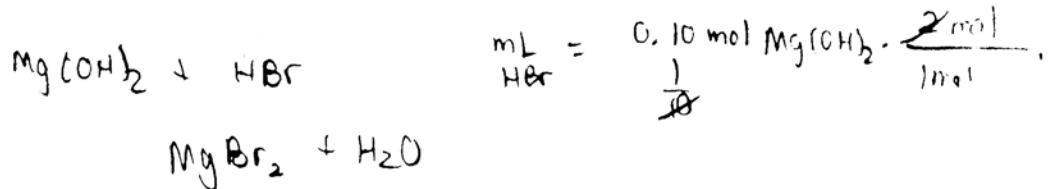
- (a) Solid magnesium hydroxide is added to a solution of hydrobromic acid.

(i) Balanced equation:

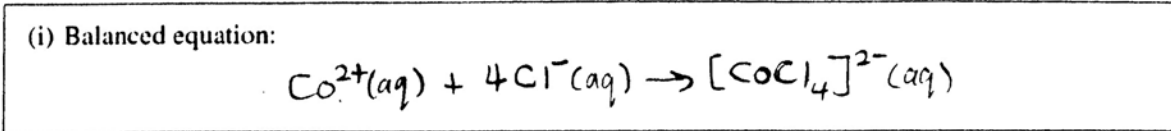


- (ii) What volume, in mL, of 2.00 M hydrobromic acid is required to react completely with 0.10 mol of solid magnesium hydroxide?

100 mL of 2.00 M HBr



(b) Excess hydrochloric acid is added to a solution of cobalt(II) nitrate to produce a coordination complex.



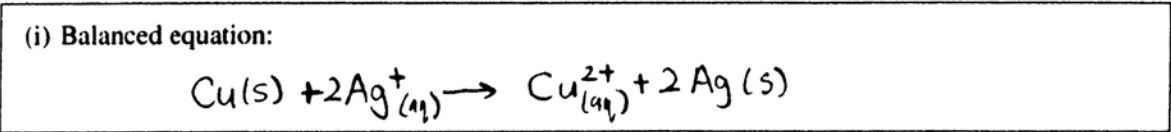
(ii) Which species in the reaction acts as a Lewis base?

Cl<sup>-</sup>

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HCl                  Co(NO<sub>3</sub>)<sub>2</sub>

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



(ii) Describe what is observed as the reaction proceeds.

As the reaction proceeds, silver Ag metal will be seen  
plating the Cu metal.

$$\text{Cu} + \text{AgNO}_3 \rightarrow \text{Cu(NO}_3)_2 + \text{Ag}$$

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

$\frac{0.01 \text{ mol}}{0.1 \text{ mol}} = 100 \text{ mL}$

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, 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:  

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

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

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

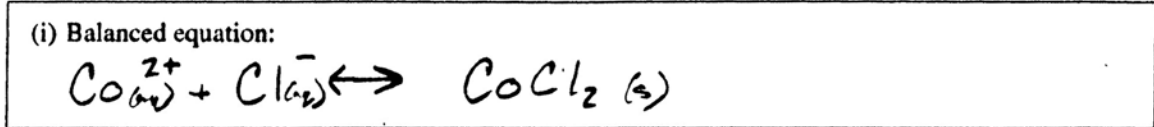
(i) Balanced equation:  

$$\text{OH}^- + \text{H}^+ \rightleftharpoons \text{H}_2\text{O}$$

(ii) What volume, in mL, of 2.00 M hydrobromic acid is required to react completely with 0.10 mol of solid magnesium hydroxide?  
100. mL of 2.00 M HBr

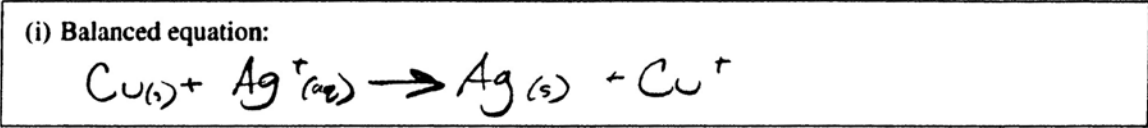
4B<sub>2</sub>

(b) Excess hydrochloric acid is added to a solution of cobalt(II) nitrate to produce a coordination complex.



(ii) Which species in the reaction acts as a Lewis base?  
Co(NO<sub>3</sub>)<sub>2</sub>

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



(ii) Describe what is observed as the reaction proceeds.  
The copper wire is plated with solid silver.

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

4C

CHEMISTRY

Part B

Time—40 minutes

NO CALCULATORS MAY BE USED FOR PART B.

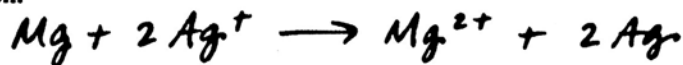
Answer Question 4 below. The Section II score weighting for this question is 10 percent.

4. For each of the following three reactions, 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:

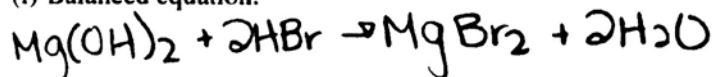


(ii) Which substance is oxidized in the reaction?

Mg is oxidized.

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

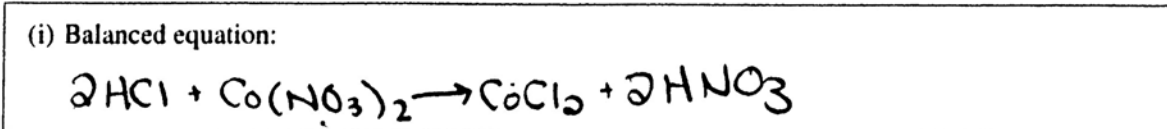
(i) Balanced equation:



(ii) What volume, in mL, of 2.00 M hydrobromic acid is required to react completely with 0.10 mol of solid magnesium hydroxide?

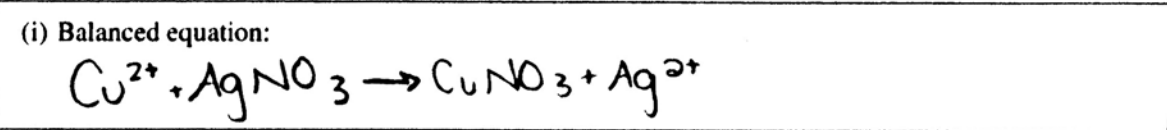
50 mL

(b) Excess hydrochloric acid is added to a solution of cobalt(II) nitrate to produce a coordination complex. 4C 2



(ii) Which species in the reaction acts as a Lewis base?  
Co(NO<sub>3</sub>)<sub>2</sub> acts as a Lewis base.

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



(ii) Describe what is observed as the reaction proceeds.  
A single-replacement reaction occurs. The wire will begin to look "fuzzy" as NO<sub>3</sub> builds up on it.

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



**AP<sup>®</sup> CHEMISTRY**  
**2011 SCORING COMMENTARY**

**Question 4**

**Overview**

This question assessed students' ability to communicate their knowledge of chemical processes. Important skills tested included writing chemical formulas for substances and communicating how these substances react with one another in the form of a balanced net-ionic equation. Additional aspects of the problem evaluated general understanding of chemical concepts presented to students in the classroom and the laboratory.

**Sample: 4A**

**Score: 15**

This response earned all 15 available points. Part (a)(i) earned 1 point for both reactants being expressed correctly, 2 points for both correct products, and 1 point for balancing both mass and charge correctly. Part (a)(ii) earned 1 point for the correct volume. Part (b)(i) earned 2 points for both correct reactants, 1 point for the correct product, and 1 point for balancing both mass and charge. Part (b)(ii) earned 1 point for identifying the Lewis base as  $\text{Cl}^-$ . Part (c)(i) earned 1 point for both reactants expressed correctly, 2 points for both correct products, and 1 point for balancing both mass and charge correctly. Part (c)(ii) earned 1 point for a correct observation. Note that although this response includes phases in all balanced equations, it was not necessary to include the phases to receive credit.

**Sample: 4B**

**Score: 11**

Part (a)(i) earned 1 product point for the water, 1 point for the reactants consistent with the product, and 1 point for balancing both mass and charge. Part (a)(ii) earned 1 point for the correct volume. Note that the volume must be based on the stoichiometry apparent in  $\text{Mg}(\text{OH})_2$ , rather than on the stoichiometry communicated in the net ionic equation. Part (b)(i) earned 2 points for both correct reactants and 1 point for the correct product. Although  $\text{CoCl}_2$  is uncharged, it is a coordination complex in the aqueous state. The balancing point was not earned, as the response does not balance the chloride ions. Part (b)(ii) earned no point because  $\text{Co}(\text{NO}_3)_2$  is not the Lewis base. Part (c)(i) earned 1 point for both reactants expressed correctly, 1 point for the product  $\text{Ag}$ , and 1 point for balancing both mass and charge. Part (c)(ii) earned 1 point for a correct observation.

**Sample: 4C**

**Score: 5**

Part (a)(i) earned 1 point for the product water and 1 point for the correct balance of both mass and charge. Part (a)(ii) earned no point as the volume is incorrect. Part (b)(i) earned 1 point for an accepted complex and 1 point for the correct balance of mass and charge. Part (b)(ii) earned no point because  $\text{Co}(\text{NO}_3)_2$  is not the Lewis base. Part (c)(i) earned 1 point only for the balance of mass and charge. Part (c)(ii) earned no point as the response incorrectly indicates that the wire looks "fuzzy" as  $\text{NO}_3$  builds up on it.