

**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.

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

The sign of $\Delta S^\circ$ is negative. One of the reactants, $\text{Cl}_2$ , 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 $\Delta S^\circ$ negative.	One point is earned for a correct answer involving entropy of a gas.
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- (b) Solid strontium hydroxide is added to a solution of nitric acid.

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

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

(i) Balanced equation:  $\text{Ba}^{2+} + \text{CO}_3^{2-} \rightarrow \text{BaCO}_3$	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) What happens to the pH of the sodium carbonate solution as the barium chloride is added to it?

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

Part B

Time—40 minutes

4A<sub>1</sub>

NO CALCULATORS MAY BE USED FOR PART B.

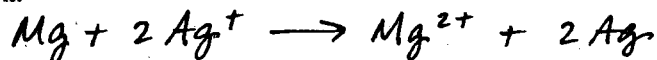
Answer Question 4 below. The Section II score weighting for this question is 10 percent.

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:

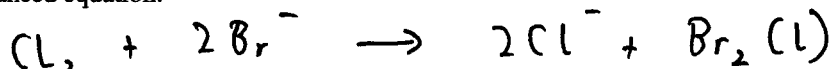


(ii) Which substance is oxidized in the reaction?

Mg is oxidized.

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

(i) Balanced equation:



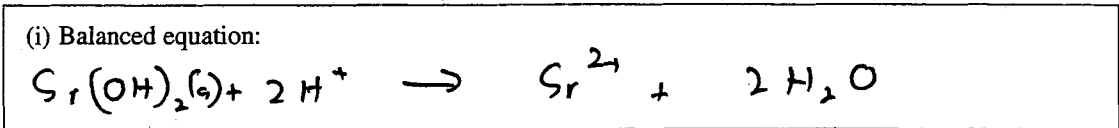
(ii) Predict the sign of  $\Delta S^\circ$  for the reaction at 25°C. Justify your prediction.

$\Delta S^\circ$  will be negative for this reaction as the reactant chlorine was a gas and the products  $\text{Br}_2$  is a liquid. The other product is also aqueous as was the other reactant.  $\therefore$  gas to liquid leads to decrease in  $\Delta S^\circ$ .

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4A2

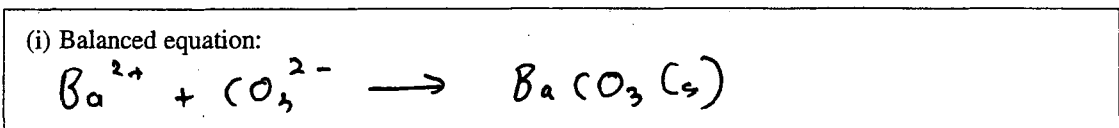
(b) Solid strontium hydroxide is added to a solution of nitric acid.



(ii) How many moles of strontium hydroxide would react completely with 500. mL of 0.40 M nitric acid?

1 mole of strontium hydroxide reacts with 2 moles of nitric acid. ∴ 0.1 mole of strontium hydroxide will react with 500 mL of 0.40 M nitric acid.

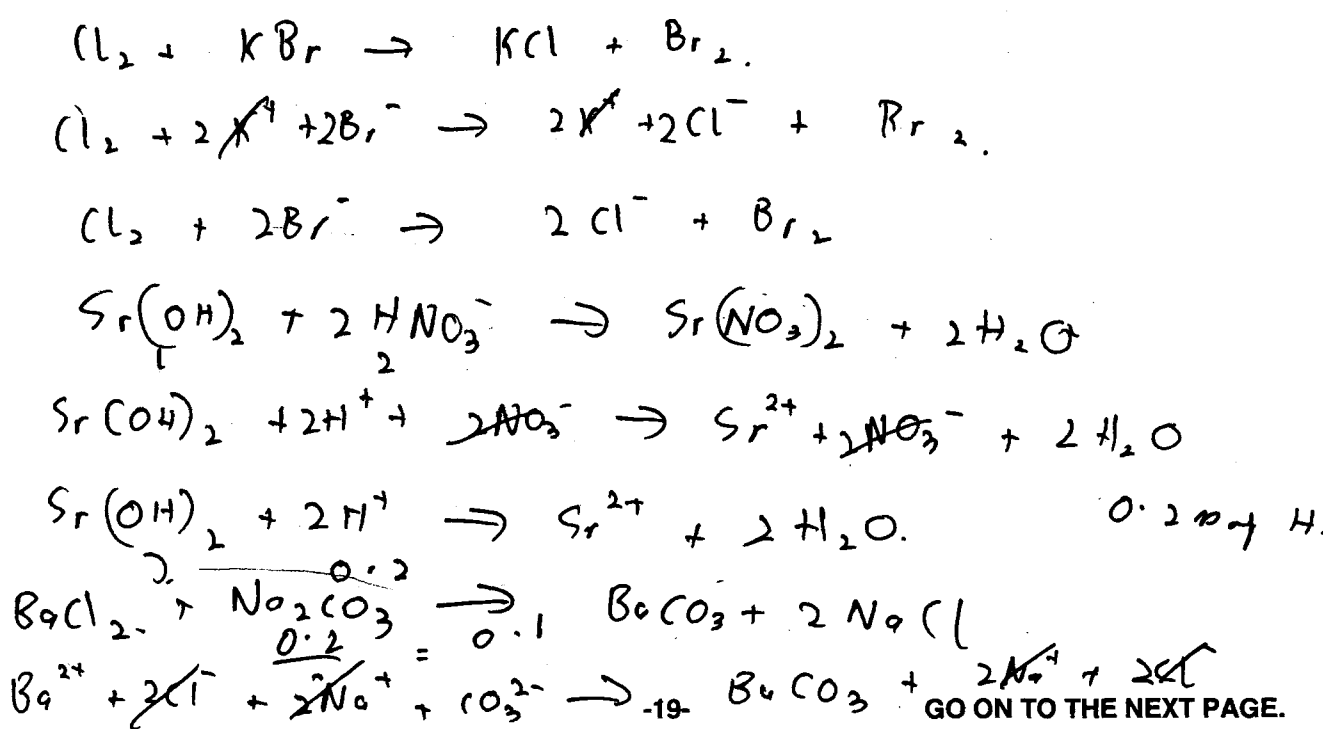
(c) A solution of barium chloride is added drop by drop to a solution of sodium carbonate, causing a precipitate to form.



(ii) What happens to the pH of the sodium carbonate solution as the barium chloride is added to it?

The pH of sodium carbonate decreases as the barium chloride is added to it.

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



GO ON TO THE NEXT PAGE.

CHEMISTRY

Part B

Time—40 minutes

NO CALCULATORS MAY BE USED FOR PART B.

4B

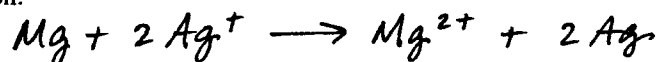
Answer Question 4 below. The Section II score weighting for this question is 10 percent.

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:

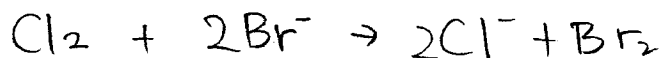


(ii) Which substance is oxidized in the reaction?

Mg is oxidized.

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

(i) Balanced equation:



(ii) Predict the sign of  $\Delta S^\circ$  for the reaction at 25°C. Justify your prediction.

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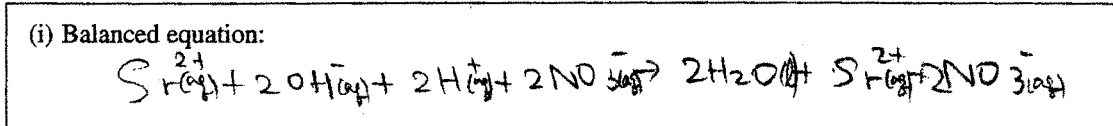


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$$\Delta G^\circ = \Delta H^\circ - T\Delta S$$

4B<sub>2</sub>

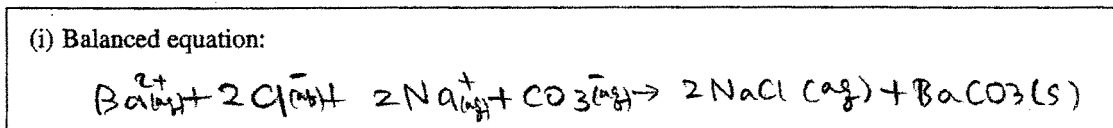
(b) Solid strontium hydroxide is added to a solution of nitric acid.



(ii) How many moles of strontium hydroxide would react completely with 500. mL of 0.40 M nitric acid?

Sr(OH)<sub>2</sub> has 2OH<sup>-</sup> per mole, so the molarity of Sr(OH)<sub>2</sub> has to be  
twice as much as HNO<sub>3</sub>.  
∴ Sr(OH)<sub>2</sub> → 0.8 M → 0.5 L × 0.8 M = 0.4 mol

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



(ii) What happens to the pH of the sodium carbonate solution as the barium chloride is added to it?

The Na<sub>2</sub>CO<sub>3</sub> solution is acidic, because H<sub>2</sub>CO<sub>3</sub> exists. When  
Ba<sup>2+</sup> is added, the CO<sub>3</sub><sup>2-</sup> will precipitate, and the pH  
will rise

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CHEMISTRY

Part B

Time—40 minutes

NO CALCULATORS MAY BE USED FOR PART B.

4C<sub>1</sub>

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.

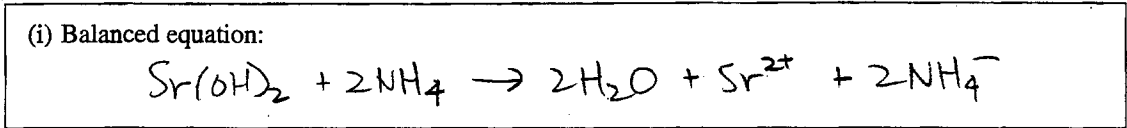
- (a) Chlorine gas, an oxidizing agent, is bubbled into a solution of potassium bromide at 25°C.

(i) Balanced equation:  

$$\text{Cl}_2(g) + 2\text{K}^+ \rightarrow 2\text{Cl}^- + 2\text{K}$$

(ii) Predict the sign of  $\Delta S^\circ$  for the reaction at 25°C. Justify your prediction.  
 $\Delta S^\circ$  will be negative because there will be less disorder. There was 1 mol of gas on the reactants but no moles of gas on the products.

(b) Solid strontium hydroxide is added to a solution of nitric acid.

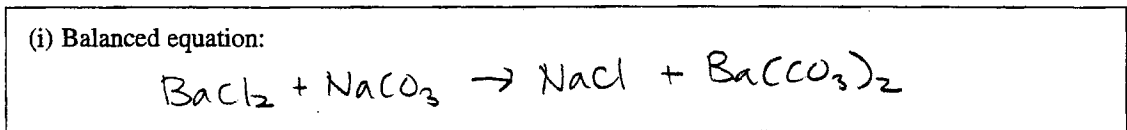


(ii) How many moles of strontium hydroxide would react completely with 500. mL of 0.40 M nitric acid?

$(.5\text{L})(.4\text{M}) = 0.2\text{M nitric acid.}$

$0.1\text{ mol Sr(OH)}_2$

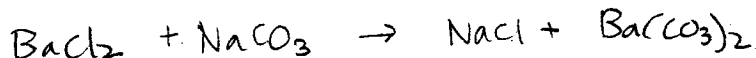
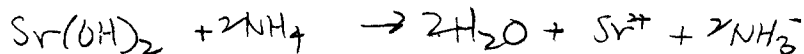
(c) A solution of barium chloride is added drop by drop to a solution of sodium carbonate, causing a precipitate to form.



(ii) What happens to the pH of the sodium carbonate solution as the barium chloride is added to it?

Nothing. because salts do not effect the pH.

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**AP<sup>®</sup> CHEMISTRY**  
**2008 SCORING COMMENTARY (Form B)**

**Question 4**

**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: 10**

In part (a)(i) 1 point was earned for correct reactants, 2 points were earned for correct products, and 1 point was earned for balancing the equation. The point was not earned in part (a)(ii). In part (b)(i) the reactant point was not earned because  $\text{Sr}(\text{OH})_2$  is shown as ions in solution instead of as a solid. The product points and the balancing point were earned. The point was not earned in part (b)(ii). In part (c)(i) the reactant point was not earned because of the inclusion of spectator ions. The product points and the balancing point were earned. The point was not earned in part (c)(ii).

**Sample: 4C**

**Score: 5**

In part (a)(i) 1 point was earned for  $\text{Cl}^-$  as a product, but the other product point and the reactant point were not earned. The balancing point was not earned because the equation is not balanced for charge. The point was earned in part (a)(ii). In part (b)(i) 2 points were earned for the products, but the reactant point and balancing point were not earned. The point was earned in part (b)(ii). No points were earned in part (c).