

**AP[®] CHEMISTRY
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.

<p>(i) Balanced equation:</p> $2 \text{OH}^- + \text{Pb}^{2+} \rightarrow \text{Pb}(\text{OH})_2$	<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) 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.

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

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

<p>The H^+ ions in acid rain react with the marble statues and the soluble compounds of Ca that are formed wash away.</p>	<p>One point is earned for a correct answer involving acid precipitation.</p>
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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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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 ΔS° for the reaction. Explain your reasoning.

The algebraic sign of ΔS° 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 H_2 gas that burns.	One point is earned for the correct answer.
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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 $[\text{Al(OH)}_4]^-$ will decrease because ...</p> <p>(If equilibrium exists), the H^+ added would react with the OH^- in solution, reducing the $[\text{OH}^-]$ 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 H^+ added would react with the $[\text{Al(OH)}_4]^-$, 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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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>O_2 would be in excess because of the stoichiometry of the reaction; 4 moles of HCl are consumed for 1 mole of O_2. (It takes only 0.75 mole of O_2 to react with 3 moles of HCl, leaving an excess of 2.25 moles of O_2.)</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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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 OH^- 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[®] CHEMISTRY
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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 ΔS° for the reaction at 25°C. Justify your prediction.

The sign of ΔS° is negative. One of the reactants, 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 ΔS° 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 H^+ in 500. mL of 0.40 M nitric acid. Because there are two moles of 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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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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