

AP[®] CHEMISTRY
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;">OR</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;">OR</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 NH_4^+ ion, which reacts with water to form NH_3 and H^+.</p> <p>OR</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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Question 4 (continued)

(c) Solid mercury(II) oxide decomposes as it is heated in an open test tube in a fume hood.

<p>(i) Balanced equation:</p> $2 \text{HgO} \rightarrow 2 \text{Hg} + \text{O}_2$	<p>One point is earned for the correct reactant.</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) 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.

<p>The mass of the contents of the test tube will decrease owing to the loss of O₂ gas to the atmosphere.</p>	<p>One point is earned for a correct answer consistent with part (i).</p>
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AP[®] CHEMISTRY
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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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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;">OR</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 S^{2-} produces the base OH^-, 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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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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AP[®] 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 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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