2023

AP® Chemistry

Sample Student Responses and Scoring Commentary

Inside:

Free-Response Question 7

- ☑ **Scoring Guidelines**
- ☑ **Student Samples**
- ☑ **Scoring Commentary**

Question 7: Short Answer — 4 points

(a) For a correct answer: **1 point**

Accept one of the following:

- *The student's drawing shows an incorrect ratio of* Sr^{2+} *and* OH^- *ions.*
- *The student's drawing is not charge-balanced.*

(b)(i) For the correct calculated value: **1 point**

$$\frac{0.043 \text{ mol } Sr^{2+}}{1 \text{ L}} \times \frac{2 \text{ mol } OH^-}{1 \text{ mol } Sr^{2+}} = 0.086 \ M \ OH^-$$

(ii) For the correct calculated value, consistent with (b)(i): **1 point**

$$K_{sp} = [Sr^{2+}][OH^-]^2 = (0.043)(0.086)^2 = 3.2 \times 10^{-4}$$

Total for part (b) **2 points**

(c) For the correct answer and a valid justification: **1 point**

Less than. Because the $Sr(NO_3)_2(aq)$ *solution already contains a common ion,* $Sr^{2+}(aq)$*, the solubility of* $Sr(OH)_2$ *will be decreased, resulting in a lower value of* $[OH^-]$.

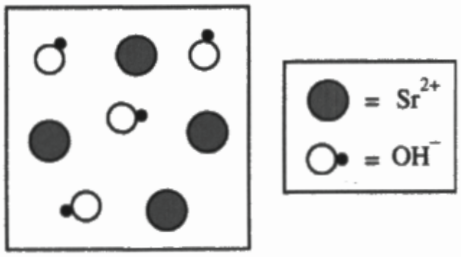
Total for question 7 **4 points**

Question 7

Begin your response to **QUESTION 7** on this page.

7. Strontium hydroxide dissolves in water according to the following equation. The K_{sp} expression for strontium hydroxide is provided.

$$Sr(OH)_2(s) \rightleftarrows Sr^{2+}(aq) + 2\,OH^-(aq) \quad K_{sp} = [Sr^{2+}][OH^-]^2$$



(a) A student draws the particulate diagram shown to represent the ions present in an aqueous solution of $Sr(OH)_2$. (Water molecules are intentionally omitted.) Identify the error in the student's drawing.

There should be double the amount of OH^- molecules since its stoichiometric coefficient in the reaction is 2. In the student's drawing there are equal numbers of particles of Sr^{2+} and OH^-, which is incorrect.

(b) The student prepares a saturated solution by adding excess $Sr(OH)_2(s)$ to distilled water and stirring until no more solid dissolves. The student then determines that $[Sr^{2+}] = 0.043\ M$ in the solution.

(i) Calculate the value of $[OH^-]$ in the solution.

$Sr(OH)_2 \rightleftarrows Sr^{2+} + 2OH^-$

		0	0
I			
C		+x	+2x
E		0.043	0.086

$[OH^-] = 2(0.043)$

$[OH^-] = 0.086\ M$

(ii) Calculate the value of K_{sp} for $Sr(OH)_2$.

$Ksp = [Sr^{2+}][OH^-]^2$ $\quad Ksp = [0.043][0.086]^2$

$Ksp = 3.2 \times 10^{-4}$

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Question 7

Continue your response to **QUESTION 7** on this page.

(c) The student prepares a second saturated solution of $Sr(OH)_2$ in aqueous 0.10 M $Sr(NO_3)_2$ instead of water. Will the value of $[OH^-]$ in the second solution be greater than, less than, or equal to the value in the first solution? Justify your answer. (Assume constant temperature.)

The value of $[OH^-]$ will be lower because of the common ion effect. Since $Sr(NO_3)_2$ is added to the solution, less $Sr(OH)_2$ is able to dissolve before the solution is saturated so the concentration of OH^- in solution is lower.

STOP

END OF EXAM

**IF YOU FINISH BEFORE TIME IS CALLED,
YOU MAY CHECK YOUR WORK ON THIS SECTION.**

THE FOLLOWING INSTRUCTIONS APPLY TO THE COVERS OF THIS SECTION II: FREE RESPONSE BOOKLET. MAKE SURE YOU HAVE DONE THE FOLLOWING:

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Question 7

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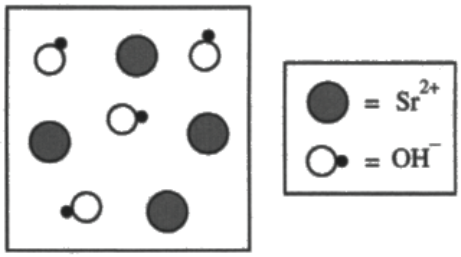

(a) A student draws the particulate diagram shown to represent the ions present in an aqueous solution of $Sr(OH)_2$. (Water molecules are intentionally omitted.) Identify the error in the student's drawing.

Due to the mole ratio, there should be double the OH^- than Sr^{2+}. The diagram shows that it's equal.

(b) The student prepares a saturated solution by adding excess $Sr(OH)_2(s)$ to distilled water and stirring until no more solid dissolves. The student then determines that $[Sr^{2+}] = 0.043\ M$ in the solution.

(i) Calculate the value of $[OH^-]$ in the solution.

$0.043 \cdot 2 = 0.086$

$[OH^-] = 0.086\ M$

(ii) Calculate the value of K_{sp} for $Sr(OH)_2$.

$(0.043)(0.086)^2 = K_{sp}$

$K_{sp} = 0.000032$

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Use a pencil or a pen with black or dark blue ink. Do NOT write your name. Do NOT write outside the box.

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Question 7

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when the 2 solutions are mixed, the Sr^{2+} ions will increase the reverse rate, however that won't change $[OH^-]$.

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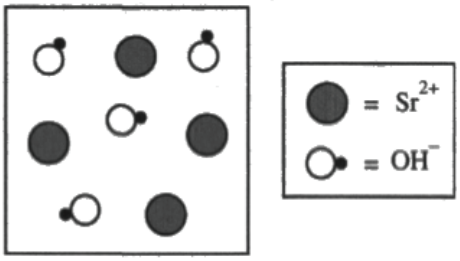

(a) A student draws the particulate diagram shown to represent the ions present in an aqueous solution of $Sr(OH)_2$. (Water molecules are intentionally omitted.) Identify the error in the student's drawing.

There should be 2 OH^- for every one Sr^{2+}

(b) The student prepares a saturated solution by adding excess $Sr(OH)_2(s)$ to distilled water and stirring until no more solid dissolves. The student then determines that $[Sr^{2+}] = 0.043\ M$ in the solution.

(i) Calculate the value of $[OH^-]$ in the solution.

$[OH^-] = 0.043$

(ii) Calculate the value of K_{sp} for $Sr(OH)_2$.

$Ksp = 0.043 \cdot 2(0.043)^2$

$Ksp = 1.6 \times 10^{-4}$

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Use a pencil or a pen with black or dark blue ink. Do NOT write your name. Do NOT write outside the box.

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Question 7

Continue your response to **QUESTION 7** on this page.

(c) The student prepares a second saturated solution of $Sr(OH)_2$ in aqueous 0.10 *M* $Sr(NO_3)_2$ instead of water. Will the value of $[OH^-]$ in the second solution be greater than, less than, or equal to the value in the first solution? Justify your answer. (Assume constant temperature.)

Less than because there will be less hydrogen ions to make OH^-

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END OF EXAM

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Question 7

Note: Student samples are quoted verbatim and may contain spelling and grammatical errors.

Overview

Question 7 presented students with a set of questions surrounding the solubility equilibrium for strontium hydroxide.

Part (a) required students to interpret a particulate-level diagram that illustrates a dissociation of $Sr(OH)_2$ into its ions. Students were expected to make a claim about how the ratio of Sr^{2+} and OH^- in the diagram is incorrectly illustrated (Learning Objective SPQ-3.B, Skill 6.A from the *AP Chemistry Course and Exam Description*).

Part (b)(i) required students to calculate $[OH^-]$ using information given about $[Sr^{2+}]$ using the stoichiometric relationship. Identifying that the relationship between $[OH^-]$ and $[Sr^{2+}]$ is 2:1, students must calculate a value of $[OH^-]$ that is double that of $[Sr^{2+}]$ (SPQ-4.A, 5.F).

Using the information provided in part (b)(i) and the calculated value of $[OH^-]$, part (b)(ii) prompted students to calculate the K_{sp} value for the insoluble hydroxide using the provided K_{sp} expression (SPQ-5.A, 5.F).

In part (c) the students were prompted with a second saturated solution of $Sr(OH)_2$ that is prepared in $Sr(NO_3)_2(aq)$, rather than pure water. Students must assess whether the value of $[OH^-]$ in the second solution is greater than, less than, or the same as the value of $[OH^-]$ in the first solution. Students must consider the impact on the equilibrium conditions if the $Sr(OH)_2$ was to be added to a solution already containing $Sr^{2+}(aq)$ ions, as compared to the original solution where $Sr(OH)_2$ was added to pure water (SPQ-5.B, 2.F).

Sample: 7A
Score: 4

The point was earned in part (a) for indicating that the OH^- to Sr^{2+} ratio should be 2:1, but in the drawing there are equal numbers of both types of ions. The point was earned in part (b)(i) for a correct calculation of $[OH^-]$. In this example $[OH^-]$ is shown to be twice $[Sr^{2+}]$. The point was earned in part (b)(ii) for a correct calculation of K_{sp}. In this example the K_{sp} expression and the expression with the substituted concentrations show the work for this calculation. The point in part (c) was earned for stating that $[OH^-]$ is lower and providing a valid justification.

Sample: 7B
Score: 3

The point in part (a) was earned for indicating that the OH^- to Sr^{2+} ratio should be 2:1, but in the drawing the ratio is 1:1. In this example the statement is made that $[OH^-]$ should be double $[Sr^{2+}]$ and that what is drawn are equal amounts of OH^- and Sr^{2+}. The point in part (b)(i) was earned for correctly calculating $[OH^-]$. The point in part (b)(ii) was earned for correctly calculating the K_{sp}. The

Question 7 (continued)

point in part (c) was not earned for stating that [OH^-] does not change. The response indicates that the reverse rate increases, but the final concentration of OH^- is based on equilibrium, not on the rate at which equilibrium is attained.

Sample: 7C
Score: 1

The point in part (a) was earned for indicating that the correct ratio of OH^- to Sr^{2+} is 2:1. The point in part (b)(i) was not earned for stating that [OH^-] equals [Sr^{2+}]. The value of [OH^-] should be twice the value of [Sr^{2+}]. The point in part (b)(ii) was not earned because the mathematical expression used to calculate the K_{sp} is incorrect. The setup shown has the 0.043 squared but NOT the 2 outside the parentheses. This results in an incorrect calculation. The point in part (c) was not earned because the explanation of the decreased [OH^-] is not associated with the increased [Sr^{2+}]. The example attempts to justify using hydrogen ions, but it is the increase in [Sr^{2+}] that causes the decrease in [OH^-].