AP® CHEMISTRY
2016 SCORING GUIDELINES

Question 6

$$Ba^{2+}(aq) + EDTA^{4-}(aq) \rightleftarrows Ba(EDTA)^{2-}(aq) \qquad K = 7.7 \times 10^{7}$$

The polyatomic ion $C_{10}H_{12}N_2O_8^{4-}$ is commonly abbreviated as $EDTA^{4-}$. The ion can form complexes with metal ions in aqueous solutions. A complex of $EDTA^{4-}$ with Ba^{2+} ion forms according to the equation above. A 50.0 mL volume of a solution that has an $EDTA^{4-}(aq)$ concentration of 0.30 *M* is mixed with 50.0 mL of 0.20 *M* $Ba(NO_3)_2$ to produce 100.0 mL of solution.

(a) Considering the value of K for the reaction, determine the concentration of $Ba(EDTA)^{2-}(aq)$ in the 100.0 mL of solution. Justify your answer.

Based on the K value, the reaction goes essentially to completion. $Ba^{2+}(aq)$ is the limiting reactant. The concentration of Ba^{2+} when the solutions are first mixed but before any reaction takes place is $0.20\ M/2 = 0.10\ M$. Thus the equilibrium concentration of $Ba(EDTA)^{2-}(aq)$ is 0.10 *M*.	1 point is earned for indicating that the equilibrium concentration of $Ba(EDTA)^{2-}(aq)$ is the same as the original concentration of Ba^{2+} when the solutions are mixed. 1 point is earned for the concentration with appropriate calculations.

(b) The solution is diluted with distilled water to a total volume of 1.00 L. After equilibrium has been reestablished, is the number of moles of $Ba^{2+}(aq)$ present in the solution greater than, less than, or equal to the number of moles of $Ba^{2+}(aq)$ present in the original solution before it was diluted? Justify your answer.

The number of moles of $Ba^{2+}(aq)$ increases because the percent dissociation of $Ba(EDTA)^{2-}(aq)$ increases as the solution is diluted. OR A mathematical justification such as the following: The dilution from 100.0 mL to 1.00 L reduces the concentrations of all species to one tenth of their original values. Immediately after the dilution, the reaction quotient, Q, can be determined as shown below. $$Q = \frac{\frac{1}{10}[Ba(EDTA)^{2-}]}{\frac{1}{10}[Ba^{2+}] \times \frac{1}{10}[EDTA^{4-}]} = 10K$$ Because $Q > K$, the net reaction will produce more reactants to move toward equilibrium, so the number of moles of $Ba^{2+}(aq)$ will be greater than the number in the original solution.	1 point is earned for stating that the number of moles of $Ba^{2+}(aq)$ will increase. 1 point is earned for a valid justification.

6A

$$Ba^{2+}(aq) + EDTA^{4-}(aq) \rightleftarrows Ba(EDTA)^{2-}(aq) \qquad K = 7.7 \times 10^{7}$$

6. The polyatomic ion $C_{10}H_{12}N_2O_8^{4-}$ is commonly abbreviated as $EDTA^{4-}$. The ion can form complexes with metal ions in aqueous solutions. A complex of $EDTA^{4-}$ with Ba^{2+} ion forms according to the equation above. A 50.0 mL volume of a solution that has an $EDTA^{4-}(aq)$ concentration of 0.30 *M* is mixed with 50.0 mL of 0.20 *M* $Ba(NO_3)_2$ to produce 100.0 mL of solution.

(a) Considering the value of *K* for the reaction, determine the concentration of $Ba(EDTA)^{2-}(aq)$ in the 100.0 mL of solution. Justify your answer.

(b) The solution is diluted with distilled water to a total volume of 1.00 L. After equilibrium has been reestablished, is the number of moles of $Ba^{2+}(aq)$ present in the solution greater than, less than, or equal to the number of moles of $Ba^{2+}(aq)$ present in the original solution before it was diluted? Justify your answer.

6.a. $0.0500L \times 0.30M = 0.015\ mol\ EDTA^{4-}$
$0.0500L \times 0.20M = 0.010\ mol\ Ba^{2+}$

$\frac{0.015\ mol}{0.100L} = 0.15M\ EDTA^{4-}$

$\frac{0.010\ mol}{0.100L} = 0.10\ mol\ Ba^{2+}$

$7.7E7 = \frac{x}{(0.15-x)(0.1-x)} \qquad x \approx 0.10M$

0.10 M $Ba(EDTA)^{2-}$ K is very large, the reaction goes almost to completion.

b. Greater than originally, there are more particles on the reactant side where Ba^{2+} is, so equilibrium shifts to left when the solution is diluted.

GO ON TO THE NEXT PAGE.

6B

$Ba^{2+}(aq) + EDTA^{4-}(aq) \rightleftarrows Ba(EDTA)^{2-}(aq)$ $\quad K = 7.7 \times 10^{7}$

6. The polyatomic ion $C_{10}H_{12}N_2O_8^{4-}$ is commonly abbreviated as $EDTA^{4-}$. The ion can form complexes with metal ions in aqueous solutions. A complex of $EDTA^{4-}$ with Ba^{2+} ion forms according to the equation above. A 50.0 mL volume of a solution that has an $EDTA^{4-}(aq)$ concentration of 0.30 *M* is mixed with 50.0 mL of 0.20 *M* $Ba(NO_3)_2$ to produce 100.0 mL of solution.

(a) Considering the value of K for the reaction, determine the concentration of $Ba(EDTA)^{2-}(aq)$ in the 100.0 mL of solution. Justify your answer.

(b) The solution is diluted with distilled water to a total volume of 1.00 L. After equilibrium has been reestablished, is the number of moles of $Ba^{2+}(aq)$ present in the solution greater than, less than, or equal to the number of moles of $Ba^{2+}(aq)$ present in the original solution before it was diluted? Justify your answer.

	Ba^{2+}	+ $EDTA^{4-}$	$\rightleftharpoons$	$Ba(EDTA)^{2-}$
R				
I		.015		
C		.015 − x		+ x
E				x

$$\frac{x}{(.01-x)(.015-x)} = 7.7\times10^{7}$$

$$\frac{x}{x^2 - .025x + (1.5\times10^{-4})}$$

K is very high

$[Ba(EDTA)^{2-}] =$ about .1 M

.01 S reacting with .01 → .01 product

.1 L

(6) It is a greater # of moles, because with the diluted solution, it needs slightly more reactants to maintain the K value

GO ON TO THE NEXT PAGE.

6C

.01 .015 .01 moles / 1 = .1M

$Ba^{2+}(aq) + EDTA^{4-}(aq) \rightleftarrows Ba(EDTA)^{2-}(aq)$ $K = 7.7 \times 10^7$

6. The polyatomic ion $C_{10}H_{12}N_2O_8^{4-}$ is commonly abbreviated as $EDTA^{4-}$. The ion can form complexes with metal ions in aqueous solutions. A complex of $EDTA^{4-}$ with Ba^{2+} ion forms according to the equation above. A 50.0 mL volume of a solution that has an $EDTA^{4-}(aq)$ concentration of 0.30 *M* is mixed with 50.0 mL of 0.20 *M* $Ba(NO_3)_2$ to produce 100.0 mL of solution.

(a) Considering the value of *K* for the reaction, determine the concentration of $Ba(EDTA)^{2-}(aq)$ in the 100.0 mL of solution. Justify your answer.

(b) The solution is diluted with distilled water to a total volume of 1.00 L. After equilibrium has been reestablished, is the number of moles of $Ba^{2+}(aq)$ present in the solution greater than, less than, or equal to the number of moles of $Ba^{2+}(aq)$ present in the original solution before it was diluted? Justify your answer.

6.

a) $\frac{[EDTA^{4-}]}{[Ba^{2+}]} = \frac{.3 \cdot .05 = .015/.1 = .15}{.2 \cdot .05 = .01/.1 = .1}$

Because K is so big the reaction will proceed fully in the forward direction, Ba^{2+} is the limiting reactant and .01 moles of $Ba(EDTA)^{2-}_{(aq)}$ will be formed and its concentration $\frac{.01}{.1} = .1M$

b) The same as, the number of moles of $Ba^{2+}_{(aq)}$ in the solution is independent of the volume of water.

GO ON TO THE NEXT PAGE.

AP® CHEMISTRY
2016 SCORING COMMENTARY

Question 6

Overview

Question 6 explored students' understanding of the equilibrium of an ionic system. Students were given an equilibrium reaction forming $Ba(EDTA)^{2-}(aq)$ from $Ba^{2+}(aq)$ and $EDTA^{4-}(aq)$. In part (a) after considering the value of K, students were asked to calculate the concentration of $Ba(EDTA)^{2-}(aq)$ after mixing 50 mL of 0.30 M $EDTA^{4-}(aq)$ and 50 mL of 0.20 M $Ba(NO_3)_2(aq)$. In part (b) students were asked to determine what would happen to the number of moles of $Ba^{2+}(aq)$ after the solution from part (a) was diluted to 1.00 L.

Sample: 6A
Score: 4

In part (a) 1 point was earned for indicating that, because K is very large, the equilibrium concentration of $Ba(EDTA)^{2-}(aq)$ is equal to the initial concentration of $Ba^{2+}(aq)$. The second point was earned for the correct concentration of $Ba(EDTA)^{2-}(aq)$ at equilibrium. In part (b) 1 point was earned for correctly indicating that the number of moles of $Ba^{2+}(aq)$ present after dilution will be greater than before dilution. The second point was earned for the explanation that dilution will cause the equilibrium to shift to the left to produce more particles, causing an increase in the number of moles of $Ba^{2+}(aq)$.

Sample: 6B
Score: 3

In part (a) 1 point was earned for correctly using the equilibrium expression to solve for the equilibrium concentration of $Ba(EDTA)^{2-}(aq)$ and indicating it is equal to the initial concentration of $Ba^{2+}(aq)$. The second point was earned for the correct concentration of $Ba(EDTA)^{2-}(aq)$ at equilibrium. In part (b) 1 point was earned for correctly indicating that the number of moles of $Ba^{2+}(aq)$ present after dilution will be greater than before dilution. The second point was not earned because the student does not provide sufficient explanation as to why more reactants are needed.

Sample: 6C
Score: 2

In part (a) 1 point was earned for indicating that, because K is large, the number of moles of $Ba(EDTA)^{2-}(aq)$ at equilibrium is equal to the initial number of moles of $Ba^{2+}(aq)$. The second point was earned for the correct concentration of $Ba(EDTA)^{2-}(aq)$ at equilibrium. In part (b) neither point was earned. The student incorrectly answers that the number of moles of $Ba^{2+}(aq)$ would be the same after dilution. The justification point was not earned because the student incorrectly states that the number of moles of $Ba^{2+}(aq)$ is independent of the volume of water.