AP Chemistry 2015

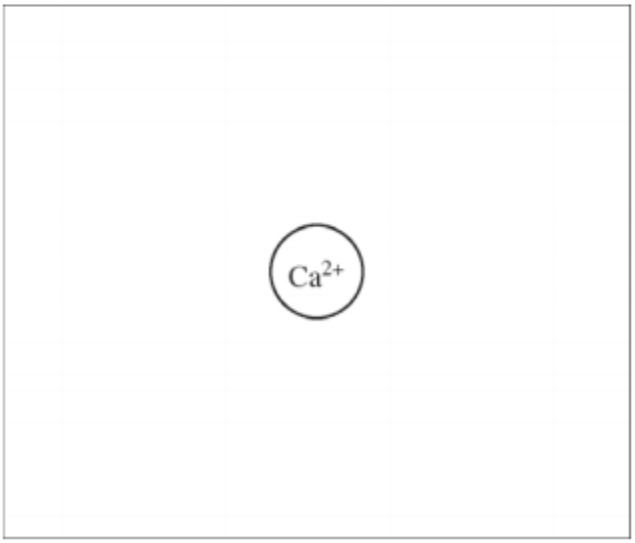
Answer the following questions about the solubility of $Ca(OH)_2$ ($K_{sp} = 1.3 \times 10^{-6}$).

(a) Write a balanced chemical equation for the dissolution of $Ca(OH)_2(s)$ in pure water.

(b) Calculate the molar solubility of $Ca(OH)_2$ in 0.10 M $Ca(NO_3)_2$.

(c) In the box below, complete a particle representation diagram that includes four water molecules with proper orientation around the Ca^{2+} ion.

Represent water molecules as  .



AP Chemistry 2016

$$C_6H_5OH(aq) + H_2O(l) \rightleftarrows C_6H_5O^-(aq) + H_3O^+(aq) \qquad K_a = 1.12 \times 10^{-10}$$

4. Phenol is a weak acid that partially dissociates in water according to the equation above.

(a) What is the pH of a 0.75 M $C_6H_5OH(aq)$ solution?

(b) For a certain reaction involving $C_6H_5OH(aq)$ to proceed at a significant rate, the phenol must be primarily in its deprotonated form, $C_6H_5O^-(aq)$. In order to ensure that the $C_6H_5OH(aq)$ is deprotonated, the reaction must be conducted in a buffered solution. On the number scale below, circle each pH for which more than 50 percent of the phenol molecules are in the deprotonated form ($C_6H_5O^-(aq)$). Justify your answer.

1 2 3 4 5 6 7 8 9 10 11 12 13 14

AP Chemistry 2016

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

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.

AP Chemistry 2017

$$N_2(g) + O_2(g) \rightleftarrows 2\,NO(g)$$

At high temperatures, $N_2(g)$ and $O_2(g)$ can react to produce nitrogen monoxide, $NO(g)$, as represented by the equation above.

(a) Write the expression for the equilibrium constant, K_p, for the forward reaction.

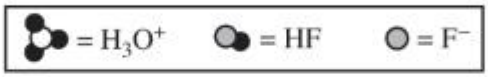
(b) A student injects $N_2(g)$ and $O_2(g)$ into a previously evacuated, rigid vessel and raises the temperature of the vessel to 2000°C. At this temperature the initial partial pressures of $N_2(g)$ and $O_2(g)$ are 6.01 atm and 1.61 atm, respectively. The system is allowed to reach equilibrium. The partial pressure of $NO(g)$ at equilibrium is 0.122 atm. Calculate the value of K_p.

AP Chemistry 2018

$$HF(aq) + H_2O(l) \rightleftarrows F^-(aq) + H_3O^+(aq)$$

5. The ionization of $HF(aq)$ in water is represented by the equation above. In a 0.0350 M $HF(aq)$ solution, the percent ionization of HF is 13.0 percent.

   (a) Two particulate representations of the ionization of HF molecules in the 0.0350 M $HF(aq)$ solution are shown below in Figure 1 and Figure 2. Water molecules are not shown. Explain why the representation of the ionization of HF molecules in water in Figure 1 is more accurate than the representation in Figure 2. (The key below identifies the particles in the representations.)



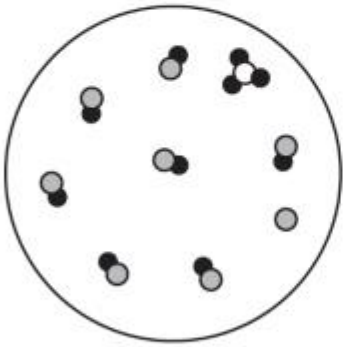


Figure 1

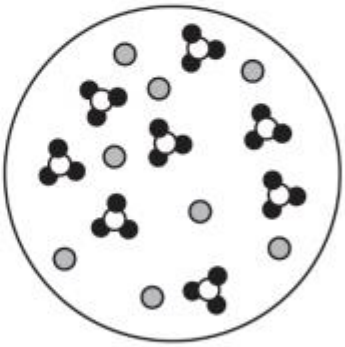


Figure 2

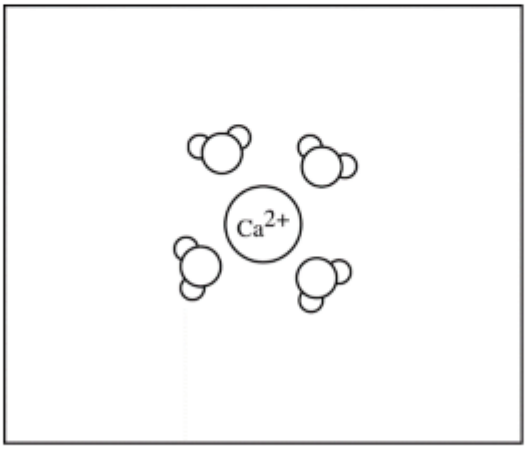
   (b) Use the percent ionization data above to calculate the value of K_a for HF.

   (c) If 50.0 mL of distilled water is added to 50.0 mL of 0.035 M $HF(aq)$, will the percent ionization of $HF(aq)$ in the solution increase, decrease, or remain the same? Justify your answer with an explanation or calculation.

AP Chemistry 2015 Solution Guide

$Ca(OH)_2 \rightleftarrows Ca^{2+} + 2\ OH^-$	1 point is earned for the correct equation.

$K_{sp} = [Ca^{2+}]\,[OH^-]^2$ $1.3 \times 10^{-6} = (0.10 + x)\,(2x)^2 \approx (0.10)\,4x^2$ [assuming $x << 0.10$] $1.3 \times 10^{-5} = 4x^2$ $x = 0.0018\ M$ Molar solubility of $Ca(OH)_2 = 0.0018\ M$	1 point is earned for the correct stoichiometry and setup. 1 point is earned for the final answer.



[The diagram should show the oxygen side of the water molecules oriented closer to the Ca^{2+} ion.]	1 point is earned for a correct diagram that shows at least three of the four water molecules oriented as described.

$K_a = \frac{[C_6H_5O^-][H_3O^+]}{[C_6H_5OH]}$ $1.12 \times 10^{-10} = \frac{x^2}{(0.75 - x)}$ Assume that $x << 0.75$. $x^2 = 8.4 \times 10^{-11}$ $x = \sqrt{8.4 \times 10^{-11}}$ $x = 9.2 \times 10^{-6}\ M$ $pH = -\log[H^+] = -\log(9.2 \times 10^{-6}) = 5.04$	1 point is earned for a correct setup and calculation of $[H^+]$. 1 point is earned for the correct setup and calculation of pH based on a correct setup for the $[H^+]$ calculation.

Numbers 10 through 14 should be circled. When pH > pK_a, the deprotonated form will predominate. $pK_a = -\log(1.12 \times 10^{-10}) = 9.95$, therefore at pH 10 and above, $[C_6H_5O^-] > [C_6H_5OH]$.	1 point is earned for circling 10–14. 1 point is earned for the justification.

AP Chemistry 2016 Solution Guide

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.

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.

AP Chemistry 2017 Solution Guide

$K_p = \dfrac{(P_{NO})^2}{(P_{N_2})(P_{O_2})}$	1 point is earned for a correct K_p expression.

$N_2(g) + O_2(g) \rightleftarrows 2\ NO(g)$ Initial 6.01 1.61 0 Change $-x$ $-x$ $+2x$ Equilibrium $6.01-x$ $1.61-x$ 0.122 $2x = 0.122$ atm $\Rightarrow$ $x = 0.0610$ atm $K_p = \dfrac{(0.122)^2}{(5.95)(1.55)} = 0.00161$	1 point is earned for the correct equilibrium partial pressures of reactants and products (may be implicit). 1 point is earned for the correct calculation of K_p.

AP Chemistry 2018 Solution Guide

HF is a weak acid and is only partially ionized. This fact is consistent with Figure 1, which shows that one out of eight (~13%) HF molecules is ionized (to form one H_3O^+ and one F^-). OR Figure 2 cannot represent HF because it represents 100% ionization of the acid.	1 point is earned for a valid explanation.

Assume $[H_3O^+] = [F^-]$ in $HF(aq)$. $\dfrac{[H_3O^+]}{0.0350\ M} = 0.130 \Rightarrow [H_3O^+] = 0.00455\ M$ $HF(aq) + H_2O(l) \rightleftarrows F^-(aq) + H_3O^+(aq)$ I 0.0350 0 ~0 C −0.00455 +0.00455 +0.00455 E 0.0304 0.00455 0.00455 $K_a = \dfrac{[H_3O^+][F^-]}{[HF]} = \dfrac{(0.00455)^2}{(0.0304)} = 6.81 \times 10^{-4}$	1 point is earned for the correct calculation of $[H_3O^+]$. 1 point is earned for a value of K_a consistent with the calculated value of $[H_3O^+]$.

The percent ionization of HF in the solution would increase. Doubling the volume of the solution decreases the initial concentration of each species by one-half; therefore, $Q = \frac{(\frac{1}{2}[H_3O^+]_i)(\frac{1}{2}[F^-]_i)}{\frac{1}{2}[HF]_i} = \frac{1}{2}K_a \Rightarrow Q < K_a$. Consequently the equilibrium position will shift toward the products and increase the percent ionization. **OR** New volume = twice original volume, thus new $[HF]_i = \frac{0.035}{2} = 0.0175\ M$ $K_a = \frac{[H_3O^+][F^-]}{[HF]} = 6.81 \times 10^{-4}$ (value from part (b)) Let $[H_3O^+] = [F^-] = x$ Then $6.81 \times 10^{-4} = \frac{(x)(x)}{(0.0175 - x)} \approx \frac{x^2}{(0.0175)} \Rightarrow x \approx 0.00345\ M$ Percent ionization = $\frac{0.00345\ M}{0.0175\ M} \times 100 = 20.\%$ $20.\% > 13.0\%$; therefore, the percent ionization increases.	1 point is earned for a correct answer and a valid explanation or calculation.