2018

AP Chemistry

Sample Student Responses and Scoring Commentary

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Question 5

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

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.)

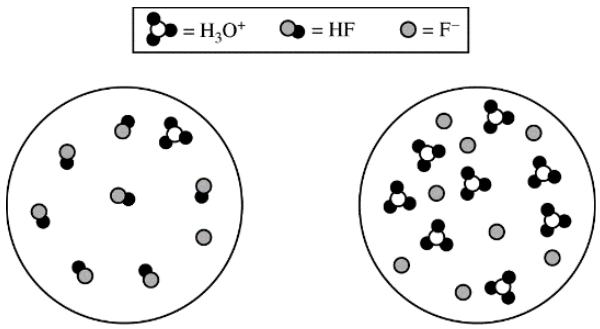

Figure 1 Figure 2

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.

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

Assume $[H_3O^+] = [F^-]$ in $HF(aq)$. $\frac{[H_3O^+]}{0.0350\ M} = 0.130 \Rightarrow [H_3O^+] = 0.00455\ M$ $HF(aq) + H_2O(l) \rightleftarrows F^-(aq) + H_3O^+(aq)$ I 0.0350 0 ~0 C −0.00455 +0.00455 +0.00455 E 0.0304 0.00455 0.00455 $K_a = \frac{[H_3O^+][F^-]}{[HF]} = \frac{(0.00455)^2}{(0.0304)} = 6.81 \times 10^{-4}$	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 $[H_3O^+]$.

Question 5 (continued)

(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.

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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.

</td>
<td>1 point is earned for a correct answer <u>and</u> a valid explanation or calculation.</td>
</tr>
</table>

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

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.)

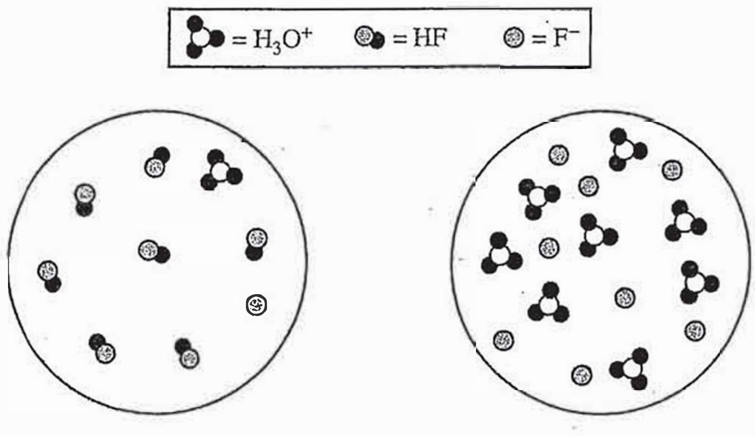

Figure 1 Figure 2

(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.

a) this is a weak acid, so few, definately not all of the HF is split and forms H_3O^+ as shown in figure 2. Instead, most don't, as shown in figure 1.

b) $HF + H_2O \rightleftharpoons F^- + H_3O^+$ $.0350M \cdot .130 = .00455M$

	HF	F^-	H_3O^+
I	.0350M	0	0
C	−.00455M	+.00455M	+.00455M
E	.0305M	.00455M	.00455 M

$$Ka = \frac{[.00455]^2}{.0305} = \boxed{6.79 \times 10^{-4}}$$

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ADDITIONAL PAGE FOR ANSWERING QUESTION 5

c) $HF + H_2O \rightleftharpoons F^- + H_3O^+$

	HF	H_2O	F^-	H_3O^+
I	~~.035~~ .018 M		0	0
C	−x		+x	+x
E	~~.035~~ .018 − x		x	x

$M_1V_1 = M_2V_2$

$.035(50.0) = x(100.0)$

$x = .0180$ M

$6.79 \times 10^{-4} = \frac{x^2}{.018 - x}$

$x = .0032$ M

$\frac{.0032}{.018} \times 100\% = 18\%$

increases

→13%

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

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.)

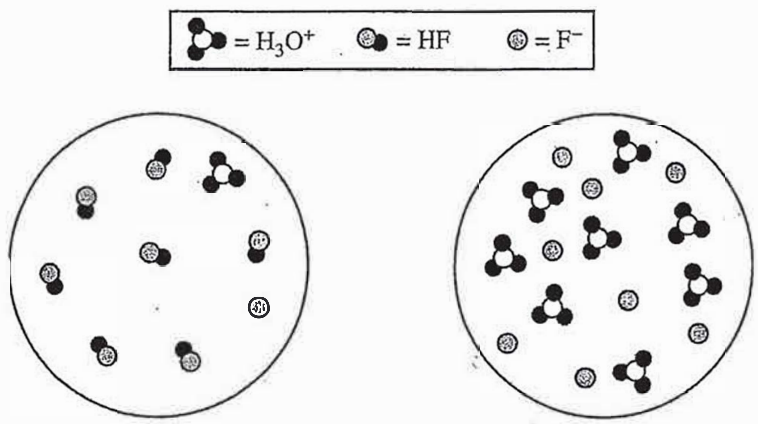

Figure 1 Figure 2

(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.

a.) When showing ionization with water, it is important to remember that only 13% of the HF was ionized. In Figure 2, all was ionized, making the represontation non suitable.

b) $HF + H_2O \rightleftarrows F^- + H_3O^+$ 13% = 0.13 · 100

	HF	F^-	H_3O^+
I	0.0350 M	0	0
C	0.00455	0.00455	0.00455
E	0.03045	0.00455	0.00455

$0.13 \times (0.0350) = 0.00455$

$K_a = \frac{[F^-][H_3O^+]}{[HF]} = \frac{[0.00455]^2}{[0.03045]} = \boxed{6.8 \times 10^{-4}}$

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(c) The percent ionization of HF would remain the same. This is due to the proportions ~~for~~ in the K_a equation having to stay constant, in terms of molarity, due to K_a being constant for the reaction

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

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.)

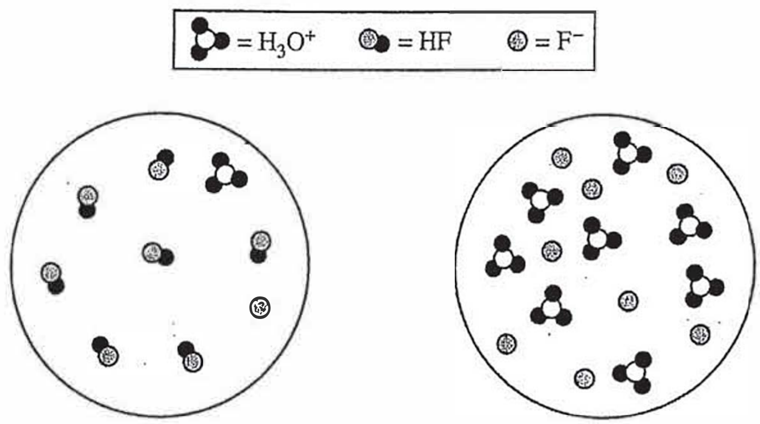

Figure 1 Figure 2

(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.

a. Figure 1 is more accurate compared to Figure 2 because it demonstrates how the HF molecules are not completely ionized. Whereas Figure 2 shows it completely ionized with no remaing HF molecules.

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b. ~~$HF \rightarrow F^- + H^+$~~

~~I | .035~~
~~C |~~
~~E |~~

$.035 \times .13 = .00455$

$K = \frac{[F^-][H^+]}{[HF]}$

$K = \frac{[.00455][.00455]}{[.035]}$

$K = 5.92 \times 10^{-4}$

c. The percent ionization will increase if 50 mL of water is added to 50 mL of HF. This is because the amount of HF molecules will increase but the water molecules do not interfere.

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Question 5

Overview

This question allowed students to demonstrate their understanding of weak acid equilibria in aqueous solution.

In part (a) students were asked to explain why Figure 1 (a particulate representation showing partial ionization of HF) was better than Figure 2 (a representation showing complete ionization of HF) in describing a 0.0350 *M* HF(*aq*) solution with 13.0 percent ionization (LO 6.11; SP 1.1, 1.4, 2.3). Responses could point out either that Figure 1 represented 13.0 percent ionization because 1 out of 8 HF molecules was ionized, or that Figure 2 showed HF to be 100 percent ionized and thus could not represent a weak acid.

In part (b) students were asked to use the percent ionization and the concentration of the HF(*aq*) to calculate the value of K_a (LO 6.5; SP 2.2). Responses needed to determine $[H_3O^+]$, $[F^-]$, and [HF] from the percent ionization information and then use them correctly in a K_a expression.

In part (c) students were presented with a hypothetical dilution of the original solution by adding 50.0 mL of H_2O to the 0.0350 *M* aqueous HF solution. They were asked to predict the impact that this dilution would have upon the percent ionization of HF and to justify their choice. The best responses calculated or qualitatively described the instantaneous reaction quotient *Q* and correctly predicted an increase in the percent ionization of HF because $Q < K_a$ (LO 6.4; SP 2.2, 6.4).

Sample: 5A
Score: 4

In part (a) the response earned 1 point because the student correctly states that HF "is a weak acid" and that "definately [*sic*] not all of the HF is split and forms H_3O^+ as shown in figure 2." The student then states that "Instead, most don't, as shown in figure 1." In part (b) the response earned 2 points. The response shows the correct calculation of $[H_3O^+]$ and recognizes that $[H_3O^+] = [F^-]$ by squaring the calculated value of $[H_3O^+]$ in the numerator of the equilibrium expression. The response also shows the calculated $[H_3O^+]$ subtracted from the initial concentration of HF because the value of $[H_3O^+]$ is more than 5 percent of the initial [HF]. The response correctly uses the calculated $[H_3O^+]$ to accurately calculate a K_a value. In part (c) 1 point was earned. A calculation of percent ionization is determined with [HF] = 0.018 *M* and the K_a value from part (b) to explain the predicted increase in the percent ionization.

Sample: 5B
Score: 3

In part (a) the response earned 1 point because the student correctly states that "In Figure 2, all was ionized, making the representation nonsuitable [*sic*]." In part (b) the response shows the correct calculation of $[H_3O^+]$ and recognizes that $[H_3O^+] = [F^-]$ by squaring the calculated value of $[H_3O^+]$ in the numerator of the equilibrium expression. The response also shows the calculated $[H_3O^+]$ subtracted from the initial concentration of HF because the value of $[H_3O^+]$ is more than 5 percent of the initial [HF]. The response correctly uses the calculated $[H_3O^+]$ to accurately calculate a K_a value. The response earned 1 point for the correct calculation of the $[H_3O^+]$ and 1 point for the correct value of K_a using the calculated $[H_3O^+]$. In part (c) no points were earned. The response

Question 5 (continued)

is incorrect: "This is due to the proportions in the K_a equation having to stay constant, in terms of molarity, due to K_a being constant for the reaction." The response recognizes that K_a is constant but does not demonstrate an understanding that Q changes with dilution because of a different number of aqueous species in the reactants and products. No point was earned.

Sample: 5C
Score: 2

In part (a) the response states that "Figure 1 is more accurate compared to Figure 2 because it demonstrates how the HF molecules are not completely ionized. Whereas Figure 2 shows it completely ionized with no remaining HF molecules." The response correctly explains the differences between the two figures to explain why Figure 1 is more accurate; thus, 1 point was earned. In part (b) the response shows the correct calculation of $[H_3O^+]$. The response recognizes that $[H_3O^+] = [F^-]$ by squaring the calculated value of $[H_3O^+]$ in the numerator of the equilibrium expression. However, the response does not show the calculated $[H_3O^+]$ subtracted from the initial concentration of HF, which is necessary because the value of $[H_3O^+]$ is more than 5 percent of the initial [HF]. Although the response has correctly used the calculated $[H_3O^+]$ in the equilibrium expression, the use of an incorrect [HF] does not lead to a correct value of K_a using the calculated $[H_3O^+]$. This response earned 1 point for the correct calculation of $[H_3O^+]$ but did not earn the point for the calculation of the correct value of K_a using the calculated $[H_3O^+]$. In part (c) the response provides a correct answer but incorrectly explains that "the amount of HF molecules will increase." The response gives no other explanation for the conclusion. No point was earned.