

Solutions to Review Problems for Acid/Base Chemistry

1. Glacial acetic acid, pure $\text{HC}_2\text{H}_3\text{O}_2$ (FW = 60.0), has a concentration of 17.54 M. If 85.5 mL of glacial acetic acid are diluted to 250 mL, what is the acetic acid concentration?

This is a dilution problem; use $M_1V_1 = M_2V_2$.

$$(17.54 \text{ M})(85.5 \text{ mL}) = M_2(250 \text{ mL})$$

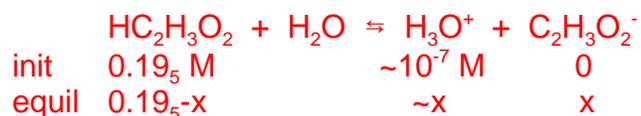
$$M_2 = 6.0_0 \text{ M}$$

2. If 26 mL of this diluted acetic acid (see Prob. 1) are further diluted to exactly 800 mL, the solution pH is 2.74. Calculate K_a for acetic acid.

First, there is a dilution, followed by an equilibrium calculation involving a solution of a weak acid.

For the dilution, $(6.0_0 \text{ M})(26 \text{ mL}) = M_2(800. \text{ mL})$ and $M_2 = 0.19_5 \text{ M}$

For the weak acid solution,



where x = increase in $[\text{C}_2\text{H}_3\text{O}_2^-]$. Since the pH is known, the $[\text{H}_3\text{O}^+]$, and hence x , is known.

$$\text{pH} = 2.74 \Rightarrow [\text{H}_3\text{O}^+] = 1.8_2 \times 10^{-3} \text{ M} = x$$

$$K_a = \frac{[\text{H}_3\text{O}^+][\text{C}_2\text{H}_3\text{O}_2^-]}{[\text{HC}_2\text{H}_3\text{O}_2]} = \frac{(1.8_2 \times 10^{-3})(1.8_2 \times 10^{-3})}{(0.19_5 - 1.8_2 \times 10^{-3})} = 1.7_1 \times 10^{-5}$$

Solutions to Review Problems for Acid/Base Chemistry

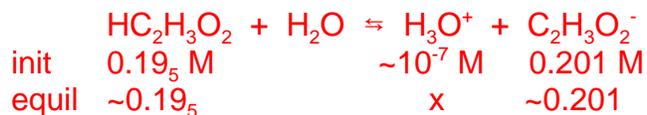
3. If 13.2 g $\text{NaC}_2\text{H}_3\text{O}_2$ (FW = 82.0) are added to the 800 mL of solution in Problem 2, what is the resulting pH?

The addition of $\text{C}_2\text{H}_3\text{O}_2^-$ to a solution of $\text{HC}_2\text{H}_3\text{O}_2$ creates a $\text{HC}_2\text{H}_3\text{O}_2 / \text{C}_2\text{H}_3\text{O}_2^-$ buffer.

initially, $[\text{HC}_2\text{H}_3\text{O}_2] = 0.19_5 \text{ M}$

and $\text{mol C}_2\text{H}_3\text{O}_2^- = 13.2 \text{ g}/82.0 \text{ g/mol} = 0.161 \text{ mol}$

$[\text{C}_2\text{H}_3\text{O}_2^-] = 0.161 \text{ mol}/0.800 \text{ L} = 0.201 \text{ M}$



$$K_a = 1.7_1 \times 10^{-5} = \frac{[\text{H}_3\text{O}^+][\text{C}_2\text{H}_3\text{O}_2^-]}{[\text{HC}_2\text{H}_3\text{O}_2]} = \frac{(x)(0.201)}{(0.19_5)}$$

$$x = 1.6_6 \times 10^{-5} \text{ M} = [\text{H}_3\text{O}^+] \Rightarrow \text{pH} = 4.78$$

Solutions to Review Problems for Acid/Base Chemistry

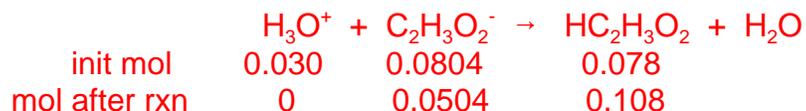
4. The resulting 800 mL of solution in Problem 3 is divided into two 400-mL samples. If 5.0 mL of 6.0 M HCl are added to one sample, and 5.0 mL of 6.0 M NaOH are added to the other, what is the resulting pH in each case?

The added HCl is neutralized by the weak base and a new buffer is formed.

$$\text{mol HCl added} = (6.0 \text{ mol/L})(0.0050 \text{ L}) = 0.030 \text{ mol}$$

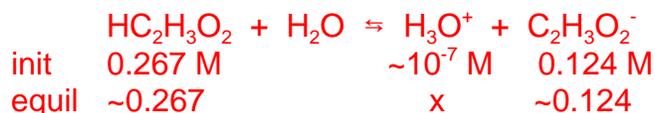
$$\text{init mol } \text{C}_2\text{H}_3\text{O}_2^- = (0.201 \text{ mol/L})(0.400 \text{ L}) = 0.0804 \text{ mol}$$

$$\text{init mol } \text{HC}_2\text{H}_3\text{O}_2 = (0.19_5 \text{ mol/L})(0.400 \text{ L}) = 0.078 \text{ mol}$$



$$[\text{HC}_2\text{H}_3\text{O}_2] = 0.108 \text{ mol}/0.405 \text{ L} = 0.267 \text{ M}$$

$$[\text{C}_2\text{H}_3\text{O}_2^-] = 0.0504 \text{ mol}/0.405 \text{ L} = 0.124 \text{ M}$$



$$K_a = 1.7_1 \times 10^{-5} = \frac{[\text{H}_3\text{O}^+][\text{C}_2\text{H}_3\text{O}_2^-]}{[\text{HC}_2\text{H}_3\text{O}_2]} = \frac{(x)(0.124)}{(0.267)}$$

$$x = 3.6_8 \times 10^{-5} \text{ M} = [\text{H}_3\text{O}^+] \Rightarrow \text{pH} = 4.43$$

Solutions to Review Problems for Acid/Base Chemistry

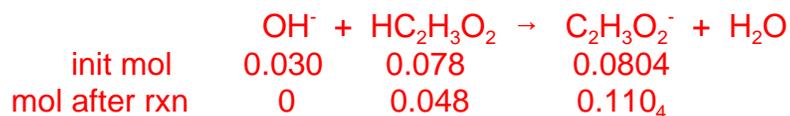
4. (continued)

The added NaOH is neutralized by the weak acid and a new buffer is formed.

$$\text{mol NaOH added} = (6.0 \text{ mol/L})(0.0050 \text{ L}) = 0.030 \text{ mol}$$

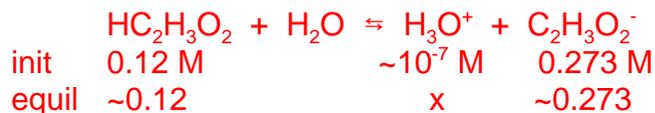
$$\text{init mol HC}_2\text{H}_3\text{O}_2 = (0.19_5 \text{ mol/L})(0.400 \text{ L}) = 0.078 \text{ mol}$$

$$\text{init mol C}_2\text{H}_3\text{O}_2^- = (0.201 \text{ mol/L})(0.400 \text{ L}) = 0.0804 \text{ mol}$$



$$[\text{HC}_2\text{H}_3\text{O}_2] = 0.048 \text{ mol}/0.405 \text{ L} = 0.12 \text{ M}$$

$$[\text{C}_2\text{H}_3\text{O}_2^-] = 0.110_4 \text{ mol}/0.405 \text{ L} = 0.273 \text{ M}$$



$$K_a = 1.7_1 \times 10^{-5} = \frac{[\text{H}_3\text{O}^+][\text{C}_2\text{H}_3\text{O}_2^-]}{[\text{HC}_2\text{H}_3\text{O}_2]} = \frac{(x)(0.273)}{(0.12)}$$

$$x = 7.5_2 \times 10^{-6} \text{ M} = [\text{H}_3\text{O}^+] \Rightarrow \text{pH} = 5.12$$

5. Calculate the pH of 10⁻⁵ M HCl.

This is a solution of a strong acid and [H₃O⁺] ~ [acid].

$$[\text{H}_3\text{O}^+] = 10^{-5} \text{ M} \Rightarrow \text{pH} = 5.0$$

Solutions to Review Problems for Acid/Base Chemistry

6. If 0.050 mL of 6.0 M HCl is added to 400 mL of 10^{-5} M HCl, what is the resulting pH?

The added HCl is combines with the initial HCl to form a new strong acid solution.

$$\text{mol H}_3\text{O}^+ \text{ added} = (6.0 \text{ mol/L})(0.000050 \text{ L}) = 0.00030 \text{ mol}$$

$$\text{init mol H}_3\text{O}^+ = (10^{-5} \text{ mol/L})(0.400 \text{ L}) = 0.000004 \text{ mol}$$

$$\text{total mol H}_3\text{O}^+ = 0.00030_4 \text{ mol}$$

$$[\text{H}_3\text{O}^+] = 0.00030_4 \text{ mol}/0.400_{05} \text{ L} = 7.6 \times 10^{-4} \text{ M}$$

$$\text{pH} = 3.12$$

(Notice that the pH of this unbuffered solution decreased by almost 2 pH units with this small addition of acid . Adding 100 times this volume of acid to a buffer (Prob. 4) changed the buffer pH by only 0.34 unit.)

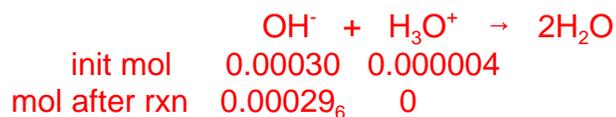
Solutions to Review Problems for Acid/Base Chemistry

7. If 0.050 mL of 6.0 M NaOH is added to 400 mL of 10^{-5} M HCl, what is the resulting pH?

The added NaOH reacts with the HCl.

$$\text{mol NaOH added} = (6.0 \text{ mol/L})(0.000050 \text{ L}) = 0.00030 \text{ mol}$$

$$\text{init mol H}_3\text{O}^+ = (10^{-5} \text{ mol/L})(0.400 \text{ L}) = 0.000004 \text{ mol}$$



The HCl is completely neutralized and you are left with a solution of a strong base.

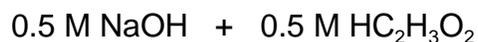
$$[\text{OH}^-] = 0.00029_6 \text{ mol}/0.400_{05} \text{ L} = 7.4 \times 10^{-4} \text{ M}$$

$$\text{pOH} = 3.13 \Rightarrow \text{pH} = 10.87$$

(Notice that the pH of this unbuffered solution increased by almost 6 pH units with this small addition of base. Adding 100 times this volume of base to a buffer (Prob. 4) changed the buffer pH by only 0.35 unit.)

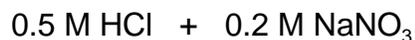
Solutions to Review Problems for Acid/Base Chemistry

8. Characterize the solution formed (strong acid, strong, base, weak acid, weak base, buffer or neutral) when equal volumes of the following are mixed. Explain.



The following reaction occurs: $\text{HC}_2\text{H}_3\text{O}_2 + \text{OH}^- \rightarrow \text{H}_2\text{O} + \text{C}_2\text{H}_3\text{O}_2^-$

Since the strong base exactly neutralizes the weak acid (same concentrations and same volumes), a solution containing a weak base ($\text{C}_2\text{H}_3\text{O}_2^-$) is formed.



NaNO_3 is a neutral electrolyte (NO_3^- is the conjugate base of a strong acid) so it will not react with the strong acid HCl. A strong acid solution is formed.



The following reaction occurs: $\text{CO}_3^{2-} + \text{H}_3\text{O}^+ \rightarrow \text{H}_2\text{O} + \text{HCO}_3^-$

Only one-half of the CO_3^{2-} is converted to HCO_3^- (the CO_3^{2-} concentration is twice that of the acid), so a $\text{CO}_3^{2-}/\text{HCO}_3^-$ buffer solution is formed.