

## Section 8.8: Buffer Systems

### Tutorial 1 Practice, page 565

1. Given:  $[\text{HC}_2\text{H}_3\text{O}_2(\text{aq})] = 2.250 \text{ mol/L}$ ;  $[\text{NaC}_2\text{H}_3\text{O}_2(\text{aq})] = 2.250 \text{ mol/L}$ ;  
 $K_a = 1.8 \times 10^{-5}$

Required: pH

Analysis:

$\text{HC}_2\text{H}_3\text{O}_2(\text{aq})$	$\rightleftharpoons$	$\text{C}_2\text{H}_3\text{O}_2^-(\text{aq})$	+	$\text{H}^+(\text{aq})$
2.250		2.250		0
$-x$		$+x$		$+x$
$2.250 - x$		$2.250 + x$		$x$

$$K_a = \frac{[\text{C}_2\text{H}_3\text{O}_2^-(\text{aq})][\text{H}^+(\text{aq})]}{[\text{HC}_2\text{H}_3\text{O}_2(\text{aq})]}$$

**Solution:**  $1.8 \times 10^{-5} = \frac{(x)(2.250 + x)}{(2.250 - x)}$

$$1.8 \times 10^{-5} \approx \frac{(x)(2.250)}{2.250}$$

$$x \approx 1.8 \times 10^{-5}$$

$$x = [\text{H}^+(\text{aq})] \approx 1.8 \times 10^{-5} \text{ mol/L}$$

$$\text{pH} = -\log(1.8 \times 10^{-5})$$

$$\text{pH} = 4.74$$

2. Given:  $[\text{HF}(\text{aq})] = 0.10 \text{ mol/L}$ ;  $[\text{F}^-(\text{aq})] = 0.10 \text{ mol/L}$ ;  $K_a = 6.6 \times 10^{-4}$

Required: pH

Analysis:

$\text{HF}(\text{aq})$	$\rightleftharpoons$	$\text{F}^-(\text{aq})$	+	$\text{H}^+(\text{aq})$
0.10		0.10		0
$-x$		$+x$		$+x$
$0.10 - x$		$0.10 + x$		$x$

$$K_a = \frac{[\text{F}^-(\text{aq})][\text{H}^+(\text{aq})]}{[\text{HF}(\text{aq})]}$$

**Solution:**  $6.6 \times 10^{-4} = \frac{(x)(0.10 + x)}{(0.10 - x)}$

$$6.6 \times 10^{-4} \approx \frac{(x)(2.250)}{2.250}$$

$$x \approx 6.6 \times 10^{-4}$$

$$x = [\text{H}^+(\text{aq})] \approx 6.6 \times 10^{-4} \text{ mol/L}$$

$$\text{pH} = -\log(6.6 \times 10^{-4})$$

$$\text{pH} = 3.18$$

3. Given:  $[\text{NH}_3(\text{aq})] = 0.15 \text{ mol/L}$ ;  $[\text{NH}_4\text{Cl}(\text{aq})] = 0.04 \text{ mol/L}$ ;  $K_b = 1.8 \times 10^{-5}$

Required: pH

Analysis:

$\text{NH}_3(\text{aq})$	$+$	$\text{H}_2\text{O}(\text{l})$	$\rightleftharpoons$	$\text{NH}_4^+(\text{aq})$	$+$	$\text{OH}^-(\text{aq})$
0.15		–		0.04		0
– $x$		–		$+ x$		$+ x$
$0.15 - x$		–		$x + 0.04$		$x$

$$K_b = \frac{[\text{NH}_4^+(\text{aq})][\text{OH}^-(\text{aq})]}{[\text{NH}_3(\text{aq})]}$$

**Solution:**  $1.8 \times 10^{-5} = \frac{(x + 0.04)(x)}{(0.15 - x)}$

$$1.8 \times 10^{-5} \approx \frac{0.04x}{0.15}$$

$$x = [\text{OH}^-(\text{aq})] \approx 6.75 \times 10^{-6} \text{ mol/L}$$

$$\text{pOH} = -\log(6.75 \times 10^{-6})$$

$$\text{pOH} = 5.17$$

$$\text{pH} = 14.0 - 5.17$$

$$\text{pH} = 8.83$$

### Section 8.8 Questions, page 567

1. A buffer uses the ratio of a conjugate pair of a weak acid or weak base to minimize the change in pH that occurs when an acid or base is added to the solution.

2. The compounds that make up a buffer are a weak acid or base and its salt.

3. (a)  $\text{H}_3\text{PO}_4(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{H}_3\text{O}^+(\text{aq}) + \text{H}_2\text{PO}_4^-(\text{aq})$  conjugate base:  $\text{H}_2\text{PO}_4^-(\text{aq})$

(b)  $\text{H}_2\text{CO}_3(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{H}_3\text{O}^+(\text{aq}) + \text{HCO}_3^-(\text{aq})$  conjugate base:  $\text{HCO}_3^-(\text{aq})$

(c)  $\text{HSO}_3^-(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{H}_3\text{O}^+(\text{aq}) + \text{SO}_3^{2-}(\text{aq})$  conjugate base:  $\text{SO}_3^{2-}(\text{aq})$

(d)  $\text{ClO}^-(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{HClO}(\text{aq}) + \text{OH}^-(\text{aq})$  conjugate acid:  $\text{HClO}(\text{aq})$

4. Answers may vary. Sample answers:

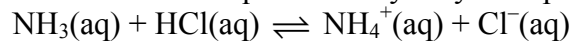
(a)  $\text{NaH}_2\text{PO}_4(\text{aq})$

(b)  $\text{KHCO}_3(\text{aq})$

(c)  $\text{MgSO}_3(\text{aq})$

(d)  $\text{NaClO}(\text{aq})$

5. The strong acid reacts with the weak base to form the weak acid, but the pH remains essentially unchanged because the change in the ratio of the conjugate acid-base pair is small. Reaction equations may vary. Sample equation:



6. In the buffer zone, an equilibrium reaction consumes the added hydrogen or hydroxide ions and causes a very small change to the pH.

7. **Given:**  $[\text{HC}_2\text{H}_3\text{O}_2(\text{aq})] = 2.63 \text{ mol/L}$ ;  $[\text{NaC}_2\text{H}_3\text{O}_2(\text{aq})] = 0.50 \text{ mol/L}$ ;  $K_a = 1.8 \times 10^{-5}$

**Required:** pH

**Analysis:**

$\text{HC}_2\text{H}_3\text{O}_2(\text{aq})$	$\rightleftharpoons$	$\text{C}_2\text{H}_3\text{O}_2^-(\text{aq})$	+	$\text{H}^+(\text{aq})$
2.63		0.50		0
$-x$		$+x$		$+x$
$2.63 - x$		$0.50 + x$		$x$

$$K_a = \frac{[\text{C}_2\text{H}_3\text{O}_2^-(\text{aq})][\text{H}^+(\text{aq})]}{[\text{HC}_2\text{H}_3\text{O}_2(\text{aq})]}$$

**Solution:**  $1.8 \times 10^{-5} = \frac{(x)(0.5 + x)}{(2.63 - x)}$

$$1.8 \times 10^{-5} \approx \frac{(x)(0.50)}{2.63}$$

$$x \approx 9.45 \times 10^{-5}$$

$$x = [\text{H}^+(\text{aq})] \approx 9.45 \times 10^{-5} \text{ mol/L}$$

$$\text{pH} = -\log(9.45 \times 10^{-5})$$

$$\text{pH} = 4.02$$

8. **Given:**  $[\text{NH}_3(\text{aq})] = 0.15 \text{ mol/L}$ ;  $[\text{NH}_4\text{Cl}(\text{aq})] = 0.04 \text{ mol/L}$ ;  $K_b = 1.8 \times 10^{-5}$

**Required:** pH

**Analysis:**

$\text{NH}_3(\text{aq})$	+	$\text{H}_2\text{O}(\text{l})$	$\rightleftharpoons$	$\text{NH}_4^+(\text{aq})$	+	$\text{OH}^-(\text{aq})$
0.15		-		0.04		0
$-x$		-		$+x$		$+x$
$0.15 - x$		-		$x + 0.04$		$x$

$$K_b = \frac{[\text{NH}_4^+(\text{aq})][\text{OH}^-(\text{aq})]}{[\text{NH}_3(\text{aq})]}$$

**Solution:**  $1.8 \times 10^{-5} = \frac{(x + 0.04)(x)}{(0.15 - x)}$

$$1.8 \times 10^{-5} \approx \frac{0.04x}{0.15}$$

$$x = [\text{OH}^-(\text{aq})] \approx 6.75 \times 10^{-6} \text{ mol/L}$$

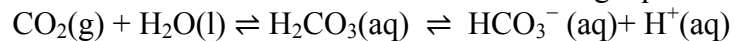
$$\text{pOH} = -\log(6.75 \times 10^{-6})$$

$$\text{pOH} = 5.17$$

$$\text{pH} = 14.0 - 5.17$$

$$\text{pH} = 8.73$$

9. Two major buffer systems in the body are the carbonate and phosphate buffer systems. The carbonate buffer is based on the following equilibrium:



Hydrogen ions added to this system react with the hydrogen carbonate ions to form carbonic acid, causing the system to shift to the left. Hydroxide ions added to the system are neutralized by the hydrogen ions present, resulting in a shift to the right.

The other major buffer system in the body is the phosphate buffer, which is based on the following equilibrium:



Hydrogen ions added to this system react with the hydrogen phosphate ion to form phosphoric acid, causing the system to shift to the left. Hydroxide ions added to this system react with the hydrogen ions ion to form water, causing the system to shift to the right.