$$\frac{x^2}{(5.6 \times 10^{-3} - x)} = 7.94 \times 10^{-5}$$

Predict whether a simplifying assumption is justified ...

$$\frac{[HA]_{initial}}{K_a} = \frac{5.6 \times 10^{-3}}{7.94 \times 10^{-5}}$$

$$\frac{[HA]_{initial}}{K_a} = 70$$

Since 70 < 100, we may not assume that $5.6 \times 10^{-3} - x \doteq 5.6 \times 10^{-3}$.

$$\frac{x^2}{(5.6 \times 10^{-3} - x)} = 7.94 \times 10^{-5}$$

$$x^2 = 7.94 \times 10^{-5}\,(5.6 \times 10^{-3} - x)$$

$$x^2 + (7.94 \times 10^{-5}x) - (4.45 \times 10^{-7}) = 0$$

$$x = \frac{-7.94 \times 10^{-5} \pm \sqrt{(7.94 \times 10^{-5})^{-2} - 4(-4.45 \times 10^{-7})}}{2}$$

$$x = 6.29 \times 10^{-4}\ \text{mol/L}$$

$$\text{pH} = -\log[H^+_{(aq)}]$$

$$= -\log[6.29 \times 10^{-4}]$$

$$\text{pH} = 3.20$$

The pH of the lactic acid in the runner's muscles is 3.20.

(b) Lactic acid buildup in muscles causes fatigue, pain, and muscle stiffness.

(c) Muscles can oxidize glucose aerobically or anaerobically to release energy. The energy released is stored temporarily in the molecule ATP that can then be used by muscles to do mechanical work. Anaerobic oxidation of glucose, however, is not very efficient. In a sprint, for example, a great deal of energy is required in a short period of time. Anaerobic oxidation supplies most of this energy but is very inefficient. Short-term energy reserves are depleted quickly and lactic acid accumulates.

Muscles used in long-distance running rely more on aerobic oxidation of glucose for their energy. When running at a comfortable pace, both systems of oxidation are used but the ratio of anaerobic: aerobic is low enough to prevent lactic acid from accumulating. As the pace increases, the anaerobic: aerobic ratio increases to the point where lactic acid begins to accumulate in the blood. This is known as the lactic acid threshold. In order to improve performance, long-distance runners try to train at the speed at which the lactic acid threshold occurs. This serves to increase the threshold and overall performance.

8.3 ACID–BASE PROPERTIES OF SALT SOLUTIONS

PRACTICE

(Page 588)

Understanding Concepts

1. (a) The ammonium ion is a weak acid with $K_a = 5.8 \times 10^{-10}$. The phosphate ion is a base with $K_b = 2.4 \times 10^{-2}$. Since K_b is larger than K_a, an ammonium phosphate solution is basic.

   (b) The ammonium ion is a weak acid with $K_a = 5.8 \times 10^{-10}$. The sulfate ion is a base with $K_b = 1.0 \times 10^{-12}$. Since K_a is larger than K_b, an ammonium sulfate solution is slightly acidic.

   (c) Magnesium oxide reacts with water to form magnesium hydroxide (a base).

   (d) $MgO_{(s)} + H_2O_{(l)} \rightarrow Mg^{2+}_{(aq)} + 2\,OH^-_{(aq)}$. This makes a solution of magnesium oxide basic.

2. A solution of sodium sulfite will be basic.

3. $NH_4NO_{3(aq)} \rightarrow NH^+_{4(aq)} + NO^-_{3(aq)}$

Since $NO^-_{3(aq)}$ is the conjugate base of a strong acid, it will not affect the pH of the solution. $NH^+_{4(aq)}$ is the conjugate acid of a weak base $NH_{3(aq)}$, so it will hydrolyze according to the equation:

$$NH^+_{4(aq)} + H_2O_{(l)} \rightleftharpoons H_3O^+_{(aq)} + NH_{3(aq)}$$

$$K_a = \frac{[H_3O^+_{(aq)}][NH_{3(aq)}]}{[NH^+_{4(aq)}]}$$

$$K_a = 5.8 \times 10^{-10}$$

ICE Table for the Hydrolysis of $NH^+_{4(aq)}$

	$NH^+_{4(aq)}$ +	$H_2O_{(l)}$ ⇌	$H_3O^+_{(aq)}$ +	$NH_{3(aq)}$
Initial concentration (mol/L)	0.30	–	0.00	0.00
Change in concentration (mol/L)	$-x$	–	$+x$	$+x$
Equilibrium concentration (mol/L)	$0.30 - x$	–	x	x

$$K_a = \frac{[H_3O^+_{(aq)}][NH_{3(aq)}]}{[NH^+_{4(aq)}]}$$

$$K_a = 5.8 \times 10^{-10}$$

$$\frac{x^2}{0.30 - x} = 5.8 \times 10^{-10}$$

Predicting whether $0.30 - x \doteq 0.30$ …

$$\frac{[HA]_{initial}}{K_a} = \frac{0.30}{5.8 \times 10^{-10}}$$

$$\frac{[HA]_{initial}}{K_a} = 5.2 \times 10^{8}$$

Since $5.2 \times 10^8 > 100$, we may assume that $0.30 - x \doteq 0.30$.

$$\frac{x^2}{0.30} \doteq 5.8 \times 10^{-10}$$

$$x^2 \doteq 1.7 \times 10^{-10}$$

$$x \doteq 1.3 \times 10^{-5}$$

Since $x = [H_3O^+_{(aq)}]$

$[H_3O^+_{(aq)}] = 1.3 \times 10^{-5}$ mol/L

pH $= -\log 1.3 \times 10^{-5}$

pH $= 4.88$

The pH of a 0.30 mol/L ammonium nitrate solution is 4.88.

4. $NH_4Br_{(aq)} \rightarrow NH^+_{4(aq)} + Br^-_{(aq)}$

Since $Br^-_{(aq)}$ is the conjugate base of a strong acid, it will not affect the pH of the solution. $NH^+_{4(aq)}$ hydrolyzes according to the equation:

$$NH^+_{4(aq)} + H_2O_{(l)} \rightleftharpoons H_3O^+_{(aq)} + NH_{3(aq)}$$

$$K_a = \frac{[H_3O^+_{(aq)}][NH_{3(aq)}]}{[NH^+_{4(aq)}]}$$

$$K_a = 5.8 \times 10^{-10}$$

ICE Table for the Hydr... $NH_{4(aq)}^+$	$NH_{4(aq)}^+$ +		$H_3O^+_{(aq)}$ +
Initial concentration (mol/L)	0.25		0.00
Change in concentration (mol/L)	$-x$		$+x$
Equilibrium concentration (mol/L)	$0.25 - x$		x

$$K_a = \frac{[H_3O^+_{(aq)}][NH_{3(aq)}]}{[NH_{4(aq)}^+]}$$

$$K_a = \ldots \times 10^{-10}$$

$$\frac{x^2}{0.25 \ldots} = \ldots .8 \times 10^{-10}$$

Predicting whether ... $x \doteq 0.25$.

$$\frac{[H]_{initial}}{K_a} = \frac{\ldots 5}{1 \ldots 0^{-10}}$$

$$\frac{[A]_{initial}}{K_a} \ldots 8$$

Since ...2 × 10 ... may assume $0.25 - x \doteq$ ...

$$\frac{x^2}{0.\ldots} \ldots 0$$

...−1...

...−5

Sinc...

$[H_3O \ldots]$ ...−5 mol/L

× 10 ... 5

The pH of ammonium bromide solution is 4.92.

5. $NH_4C_2H_3O_{2(aq)} + C_2H_3O_{2(aq)}^{-}$. The ammonium ion is a weak acid with $K_a = 5.8 \times$ ... is a weak base ...6 × 10−10 ... Since K_b and K_a are similar, an ammonium acetate solutio...

Making Connec...

6. Fertilizers contain ammonium compounds, which hydrolyze to produce acidic solutions, ar...

PRACTICE

(Page 589)

Understanding Co...

7. $HCO_{3(aq)}^-$, $HS_{(aq)}^-$, ...$_{q)}$, $H_2PO_{4(aq)}^-$, HS... $HSO_{3(aq)}^-$, $HC_2O_{4(aq)}^-$

8. (a) acidic
   (b) basic

PRACTICE

(Page 591)

Understanding Concepts

9. (a) $Na_2O_{(s)} + H_2O_{(l)} \rightleftharpoons 2\,Na^+_{(aq)} + 2$

$H_2O_{(l)} \rightleftharpoons \quad H_3O^+_{(aq)} + HSO^-_{3(aq)}$

ections

dioxide exhaled by the visitors case the acidity of the moisture in the caves, according to the

l equation:

$+ H_2O_{(l)} \rightleftharpoons H^+_{(aq)} + HCO^-_{3(aq)}$

reased acidity can accelerate the d g of the cave structures:

$CaCO_{3(s)} \rightleftharpoons Ca^{2+}_{(aq)} + HCO^-_{3(aq)}$

le solutions include providing air ci n systems or large fans that would prevent carbon dioxide gas accumulating.

s supporting the use of fluoride:

studies of large populations suggest ther fluoridation does prevent tooth decay.

ts against the use of fluoride:

other studies suggest that the evidenc pport that water fluoridation prevents tooth decay is inconclu-

isks associated with long-term exposure ace amounts of fluoride have not been established.

effects of fluoride on aquatic life have n n thoroughly studied.

e studies suggest that prolonged exposure oride is associated with a condition known as skeletal fluorosis gradual deterioration of bone.

oride can be administered in more direct what do not threaten the environment.

CE

4)

tanding Concepts

Lewis acid: $H^+_{(aq)}$; Lewis base: $OH^-_{(aq)}$

Lewis acid: $H^+_{(aq)}$; Lewis base: $NH_{3(aq)}$

ON 8.3 QUESTIONS

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rstanding Concepts

) Neutral. The sodium ion, being a member of Group 1, does not hydrolyze. The chloride ion is an extremely weak base and therefore also does not hydrolyze.

) Acidic. Chloride does not hydrolyze. Aluminum ions will hydrolyze according to the equation

$Al(H_2O)^{3+}_{6(aq)} \rightleftharpoons Al(H_2O)_5(OH)^{2+}_{(aq)} + H^+_{(aq)}$

c) Basic. The sodium ion does not hydrolyze. Carbonate will hydrolyze to release hydroxide ions.

$CO^{2-}_{3(aq)} + H_2O_{(l)} \rightleftharpoons OH^-_{(aq)} + HCO^-_{3(aq)}$

The ammonium ion is a weak acid with $K_a = 5.8 \times 10^{-10}$. The carbonate ion is a base with $K_b = 2.1 \times 10^{-4}$. Since K_b is larger than K_a, an ammonium carbonate solution is basic.

According to Table C7 in the Appendix, the strongest possible acid is perchloric acid and the strongest possible base is the hydroxide ion, $OH^-_{(aq)}$ – the base released when the hydroxide ion dissociates. However, for all practical purposes, the concentration of oxide in a solution of the hydroxide ion is zero.

4. $BeCl_{2(aq)}$ will turn litmus red because the $Be^{2+}_{(aq)}$ hydrolyzes to release $H^+_{(aq)}$.

5. (a) acidic

(b) basic

Applying Inquiry Skills

6. **Analysis**

$Na_2O_{(s)}$	basic
$MgO_{(s)}$	basic