

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

Predict whether a simplifying assumption is justified ...

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

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

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

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

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

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

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

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

$$\begin{aligned} \text{pH} &= -\log[\text{H}_{(\text{aq})}^+] \\ &= -\log[6.29 \times 10^{-4}] \end{aligned}$$

$$\text{pH} = 3.20$$

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

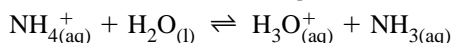
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Understanding Concepts

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) $\text{MgO}_{(\text{s})} + \text{H}_2\text{O}_{(\text{l})} \rightarrow \text{Mg}_{(\text{aq})}^{2+} + 2 \text{OH}_{(\text{aq})}^-$. This makes a solution of magnesium oxide basic.
2. A solution of sodium sulfite will be basic.
3. $\text{NH}_4\text{NO}_{3(\text{aq})} \rightarrow \text{NH}_{4(\text{aq})}^+ + \text{NO}_{3(\text{aq})}^-$

Since NO_3^- is the conjugate base of a strong acid, it will not affect the pH of the solution. NH_4^+ is the conjugate acid of a weak base NH_3 , so it will hydrolyze according to the equation:



$$K_a = \frac{[\text{H}_3\text{O}^+][\text{NH}_3]}{[\text{NH}_4^+]}$$

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

ICE Table for the Hydrolysis of NH_4^+				
	NH_4^+	$\text{H}_2\text{O} \rightleftharpoons$	H_3O^+	NH_3
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

$$K_a = \frac{[\text{H}_3\text{O}^+][\text{NH}_3]}{[\text{NH}_4^+]}$$

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

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

Predicting whether $0.30 - x \doteq 0.30$...

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

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

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

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

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

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

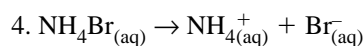
$$\text{Since } x = [\text{H}_3\text{O}^+]$$

$$[\text{H}_3\text{O}^+] = 1.3 \times 10^{-5} \text{ mol/L}$$

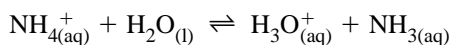
$$\text{pH} = -\log 1.3 \times 10^{-5}$$

$$\text{pH} = 4.88$$

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



Since Br^- is the conjugate base of a strong acid, it will not affect the pH of the solution. NH_4^+ hydrolyzes according to the equation:



$$K_a = \frac{[\text{H}_3\text{O}^+][\text{NH}_3]}{[\text{NH}_4^+]}$$

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

ICE Table for the Hydrolysis of $\text{NH}_4^+(\text{aq})$				
	$\text{NH}_4^+(\text{aq})$	$\text{H}_2\text{O}(\text{l}) \rightleftharpoons$	$\text{H}_3\text{O}^+(\text{aq})$	$\text{NH}_3(\text{aq})$
Initial concentration (mol/L)	0.25	—	0.00	0.00
Change in concentration (mol/L)	$-x$	—	$+x$	$+x$
Equilibrium concentration (mol/L)	$0.25 - x$	—	x	x

$$K_a = \frac{[\text{H}_3\text{O}^+(\text{aq})][\text{NH}_3(\text{aq})]}{[\text{NH}_4^+(\text{aq})]}$$

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

$$\frac{x^2}{0.25 - x} = 5.8 \times 10^{-10}$$

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

$$\frac{[\text{HA}]_{\text{initial}}}{K_a} = \frac{0.25}{5.8 \times 10^{-10}}$$

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

Since $5.2 \times 10^8 > 100$, we may assume that $0.25 - x \doteq 0.25$.

$$\frac{x^2}{0.25} \doteq 5.8 \times 10^{-10}$$

$$x^2 \doteq 1.5 \times 10^{-10}$$

$$x \doteq 1.2 \times 10^{-5}$$

$$\text{Since } x = [\text{H}_3\text{O}^+(\text{aq})]$$

$$[\text{H}_3\text{O}^+(\text{aq})] = 1.2 \times 10^{-5} \text{ mol/L}$$

$$\text{pH} = -\log 1.2 \times 10^{-5}$$

$$\text{pH} = 4.92$$

The pH of a 0.25 mol/L ammonium bromide solution is 4.92.

5. $\text{NH}_4\text{C}_2\text{H}_3\text{O}_2(\text{aq}) \rightarrow \text{NH}_4^+(\text{aq}) + \text{C}_2\text{H}_3\text{O}_2^-(\text{aq})$. The ammonium ion is a weak acid with $K_a = 5.8 \times 10^{-10}$. The acetate ion is a weak base with $K_b = 5.6 \times 10^{-10}$. Since K_b and K_a are similar, an ammonium acetate solution is essentially neutral.

Making Connections

6. Fertilizers containing ammonium compounds, which hydrolyze to produce acidic solutions, are ideal for evergreens.

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Understanding Concepts

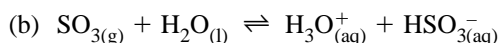
7. $\text{HCO}_3^-(\text{aq})$, $\text{HS}^-(\text{aq})$, $\text{HPO}_4^{2-}(\text{aq})$, $\text{H}_2\text{PO}_4^-(\text{aq})$, $\text{HSO}_4^-(\text{aq})$, $\text{HSO}_3^-(\text{aq})$, $\text{HC}_2\text{O}_4^-(\text{aq})$
 8. (a) acidic
 (b) basic

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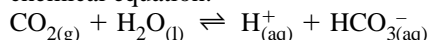
Understanding Concepts

9. (a) $\text{Na}_2\text{O}(\text{s}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons 2 \text{Na}^+(\text{aq}) + 2 \text{OH}^-(\text{aq})$

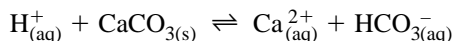


Making Connections

10. (a) Carbon dioxide exhaled by the visitors can increase the acidity of the moisture in the caves, according to the chemical equation:



The increased acidity can accelerate the dissolving of the cave structures:



- (b) Possible solutions include providing air circulation systems or large fans that would prevent carbon dioxide gas from accumulating.
11. Arguments supporting the use of fluoride:
- Some studies of large populations suggest that water fluoridation does prevent tooth decay.

Arguments against the use of fluoride:

- Some other studies suggest that the evidence to support that water fluoridation prevents tooth decay is inconclusive.
- The risks associated with long-term exposure to trace amounts of fluoride have not been established.
- The effects of fluoride on aquatic life have not been thoroughly studied.
- Some studies suggest that prolonged exposure to fluoride is associated with a condition known as skeletal fluorosis – a gradual deterioration of bone.
- Fluoride can be administered in more direct ways that do not threaten the environment.

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Understanding Concepts

12. (a) Lewis acid: $\text{H}_{(aq)}^+$; Lewis base: $\text{OH}_{(aq)}^-$
- (b) Lewis acid: $\text{H}_{(aq)}^+$; Lewis base: $\text{NH}_{3(aq)}$

SECTION 8.3 QUESTIONS

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Understanding Concepts

- (a) 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.
- (b) Acidic. Chloride does not hydrolyze. Aluminum ions will hydrolyze according to the equation

$$\text{Al}(\text{H}_2\text{O})_6^{3+} \rightleftharpoons \text{Al}(\text{H}_2\text{O})_5(\text{OH})^{2+} + \text{H}_{(aq)}^+$$
- (c) Basic. The sodium ion does not hydrolyze. Carbonate will hydrolyze to release hydroxide ions.

$$\text{CO}_3^{2-} + \text{H}_2\text{O}_{(l)} \rightleftharpoons \text{OH}_{(aq)}^- + \text{HCO}_3^-(\text{aq})$$
- 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, $\text{OH}_{(aq)}^-$ – 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.
- $\text{BeCl}_{2(aq)}$ will turn litmus red because the $\text{Be}_{(aq)}^{2+}$ hydrolyzes to release $\text{H}_{(aq)}^+$.
- (a) acidic
(b) basic

Applying Inquiry Skills

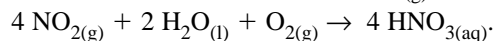
6. Analysis

$\text{Na}_2\text{O}_{(s)}$	basic
$\text{MgO}_{(s)}$	basic

As ₂ O _{3(s)}	insoluble – no solution produced. The water remains neutral.
SiO _{2(s)}	insoluble – no solution produced. The water remains neutral.
P ₂ O _{3(s)}	acidic
SO _{3(g)}	acidic
Cl ₂ O _(g)	acidic

Extension

7. Rainwater containing dissolved NO_{2(g)} is acidic because of the formation of nitric acid in this reaction:



8.4 ACID–BASE TITRATION

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Understanding Concepts

- (a) pH 7
(b) Since this is a titration of a strong acid with a strong base, the equivalence point occurs at pH 7. Any indicator with pH 7 within its range would be suitable, e.g., bromothymol blue, litmus, neutral red, phenol red.

$$\begin{aligned}
 2. \quad n_{\text{HI}} &= V_{\text{HI}} \times C_{\text{HI}} \\
 &= 11 \text{ mL} \times 0.18 \text{ mol/L} \\
 &= 1.98 \text{ mmol} \quad (\text{extra digits carried})
 \end{aligned}$$

$$\begin{aligned}
 n_{\text{HI}} &= n_{\text{NaOH required}} \\
 C_{\text{NaOH}} &= \frac{n_{\text{NaOH}}}{V_{\text{NaOH}}} \\
 V_{\text{NaOH}} &= \frac{n_{\text{NaOH}}}{C_{\text{NaOH}}} \\
 &= \frac{1.98 \text{ mmol}}{0.23 \text{ mol/L}}
 \end{aligned}$$

$$V_{\text{NaOH}} = 8.6 \text{ mL}$$

8.6 mL of 0.23 mol/L sodium hydroxide is required to reach the equivalence point.

Applying Inquiry Skills

- (a) The last drop is washed into the flask because the titrant volume level in the buret already includes the volume of the drop.
(b) The results of the titration depend only on the moles of acid or base present, not their concentration. Adding water changes concentration but not the moles present.

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Understanding Concepts

- (a)

ICE Table for the Ionization of HCO ₂ H _(aq)			
	HCO ₂ H _(aq) ⇌	H ⁺ _(aq) +	CO ₂ H ⁻ _(aq)
Initial concentration (mol/L)	0.20	0.00	0.00
Change in concentration (mol/L)	-x	+x	+x
Equilibrium concentration (mol/L)	0.20 - x	x	x