Section 8.6: Acid–Base Properties of Salt Solutions

Tutorial 1 Practice, page 534

1. Given: $[NaCHO_2(aq)] = 0.35$ mol/L; $K_a = 1.8 \times 10^{-4}$

Required: pH

Analysis:

$CHO_2^-(aq)$	+ $H_2O(l)$ $\rightleftharpoons$	$HCHO_2(aq)$	+ $OH^-(aq)$
0.35	−	0	0
$-x$	−	$+x$	$+x$
$0.35 - x$	−	x	x

$$K_b = \frac{K_w}{K_a}$$

$$K_b = \frac{1.0 \times 10^{-14}}{1.8 \times 10^{-4}}$$

$K_b = 5.555 \times 10^{-11}$ (2 extra digits carried)

$$K_b = \frac{[HCHO_2(aq)][OH^-(aq)]}{[CHO_2^-(aq)]}$$

Solution: $$5.555 \times 10^{-11} = \frac{(x)(x)}{(0.35 - x)}$$

$$5.555 \times 10^{-11} \approx \frac{(x)(x)}{0.35}$$

$x^2 \approx 1.943 \times 10^{-11}$

$x = [OH^-(aq)]$

$\approx 4.408 \times 10^{-6}$ mol/L

$pOH = -\log(4.408 \times 10^{-6})$

$pOH = 5.356$

$pH = 14.000 - 5.356$

$pH = 8.64$

2. Given: $[NaClO(aq)] = 0.85$ mol/L; $K_a = 3.5 \times 10^{-8}$

Required: pH

Analysis:

$ClO^-(aq)$	+ $H_2O(l)$ $\rightleftharpoons$	$HClO(aq)$	+ $OH^-(aq)$
0.85	−	0	0
$-x$	−	$+x$	$+x$
$0.85 - x$	−	x	x

$$K_b = \frac{K_w}{K_a}$$

$$K_b = \frac{1\times10^{-14}}{3.5\times10^{-8}}$$

$K_b = 2.86 \times 10^{-7}$

$$K_b = \frac{[HClO(aq))][OH^-(aq)]}{[ClO^-(aq)]}$$

Solution: $2.86 \times 10^{-7} = \frac{(x)(x)}{(0.85 - x)}$

$$2.86 \times 10^{-7} \approx \frac{(x)(x)}{0.85}$$

$$x^2 \approx 2.431\times10^{-7}$$

$x = [OH^-(aq)]$

$\approx 4.9305 \times 10^{-4}$ mol/L

$pOH = -\log(4.9305 \times 10^{-4})$

$pOH = 3.307$

$pH = 14.0 - 3.307$

$pH = 10.69$

Tutorial 2 Practice, page 536

1. Given: $[NH_4Cl(aq)] = 0.525$ mol/L; $K_b = 1.8 \times 10^{-5}$

Required: pH

Analysis:

$NH_4^+(aq)$ $\rightleftharpoons$	$NH_3(aq)$ +	$H^+(aq)$
0.525	0	0
$-x$	$+x$	$+x$
$0.525 - x$	x	x

$$K_a = \frac{K_w}{K_b}$$

$$K_a = \frac{1.0\times10^{-14}}{1.8\times10^{-5}}$$

$K_a = 5.555 \times 10^{-10}$ (2 extra digits carried)

$$K_a = \frac{[NH_3(aq))][H^+(aq)]}{[NH_4^+(aq)]}$$

Solution: $5.555 \times 10^{-10} = \dfrac{(x)(x)}{(0.525 - x)}$

$5.555 \times 10^{-10} \approx \dfrac{(x)(x)}{0.525}$

$x \approx 2.91 \times 10^{-10}$

$x = [H^+(aq)]$

$\approx 1.71 \times 10^{-5}$ mol/L

$pH = -\log(1.71 \times 10^{-5})$

$pH = 4.77$

2. Given: $[DCl(aq)] = 0.0250$ mol/L; $K_b = 1.62 \times 10^{-6}$

Required: pH

Analysis:

$D^+(aq)$ +	$H_2O(l)$	$\rightleftharpoons$	DOH (aq) +	$H^+(aq)$
0.0250	−		0	0
$-x$	−		$+x$	$+x$
$0.0250 - x$	−		x	x

$K_a = \dfrac{K_w}{K_b}$

$K_a = \dfrac{1.0 \times 10^{-14}}{1.62 \times 10^{-6}}$

$K_a = 6.17 \times 10^{-9}$

$K_a = \dfrac{[DOH(aq))][H^+(aq)]}{[D^+(aq)]}$

Solution: $6.17 \times 10^{-9} = \dfrac{(x)(x)}{(0.0250 - x)}$

$6.17 \times 10^{-9} \approx \dfrac{(x)(x)}{0.0250}$

$x^2 \approx 1.54 \times 10^{-10}$

$x = [H^+(aq)]$

$\approx 1.24 \times 10^{-5}$ mol/L

$pH = -\log(1.24 \times 10^{-5})$

$pH = 4.907$

Tutorial 3 Practice, page 538

1. The solution will be basic because the metal oxide will react with water to form hydroxide ions:

$CuO(aq) + 2\ H_2O(l) \rightleftharpoons Cu^{2+}(aq) + 2\ OH^-(aq)$

2. The solution will be acidic. NO_2 is a non-metal oxide. Non-metallic oxides increase the concentration of hydrogen ions in water, so the solution will be acidic.

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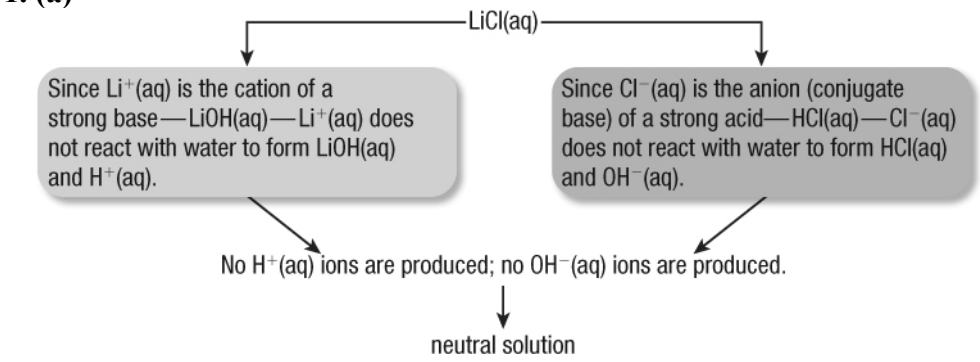
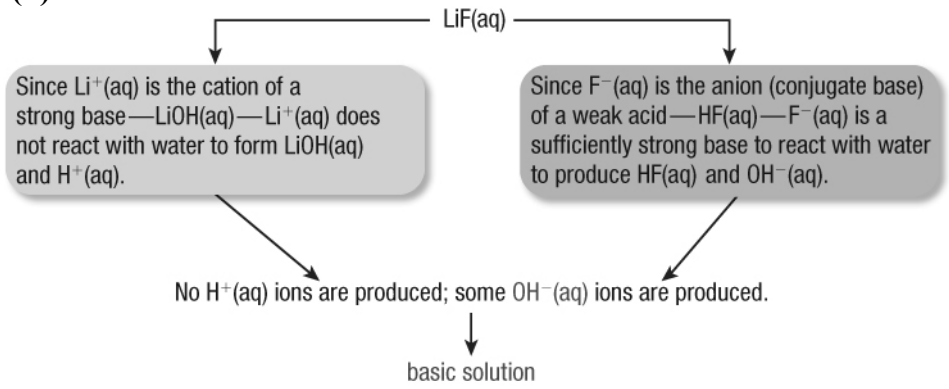
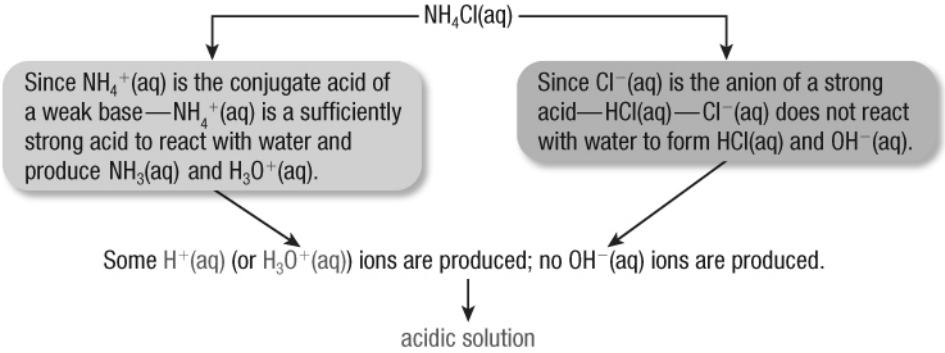
1. (a)



(b)



(c)



2. (a) The pH will be greater than 7 because the sulfite ion is the conjugate base of a weak (HSO_3^-). The sodium ion is too weak of a base to react with water to form hydroxide ions.
(b) The pH will be less than 7 because the ammonium ion is a weak acid and the methanoate ion is a weak base. This solution is predicted to be acidic because the K_a of the ammonium ion is greater than the K_b of the methanoate ion.
(c) The pH will be 7 because neither the magnesium nor sulfate will hydrolyze.

3.

Type of salt	Examples	Comment	pH of solution
Cation of a Group 1 or Group 2 element, other than Be; anion is from strong acid	KCl(aq), NaCl(aq), $NaNO_3$(aq)	Neither of the ions acts as an acid or a base	neutral
Cation of a Group 1 or Group 2 element, other than Be; anion is from weak acid	$NaC_2H_3O_2$(aq), KCN(aq), NaF(aq)	Anion acts as a base; cation has no effect on pH	basic
Cation is conjugate acid of weak base; anion is from strong acid	NH_4Cl(aq), NH_4NO_3(aq)	Cation acts as an acid; anion has no effect on pH	acidic
Cation is conjugate acid of weak base; anion is conjugate base of weak acid	$NH_4C_2H_3O_2$(aq), NH_4CN(aq)	Cation acts as an acid; anion acts as a base	acidic if Ka > Kb basic if Kb > Ka neutral if Ka = Kb
Cation is highly charged metal ion; anion is from strong acid	$Al(NO_3)_3$(aq), $FeCl_3$(aq)	Hydrated cation acts as an acid; anion has no effect on pH	acidic

4. (a) Given: $[NH_4NO_3(aq)] = 0.30$ mol/L; $K_a = 5.8 \times 10^{-10}$

Required: pH

Analysis:

$NH_4^+(aq)$ $\rightleftharpoons$	$NH_3(aq)$ +	$H^+(aq)$
0.30	0	0
$-x$	$+x$	$+x$
$0.30 - x$	x	x

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

$$K_a = \frac{[NH_3(aq)][H^+(aq)]}{[NH_4^+(aq)]}$$

Solution:

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

$$5.8 \times 10^{-10} \approx \frac{(x)(x)}{0.30}$$

$$x^2 \approx 1.74 \times 10^{-10}$$

$$x = [H^+(aq)]$$

$$\approx 1.319 \times 10^{-5} \text{ mol/L}$$

$$pH = -\log(1.319 \times 10^{-5})$$

$$pH = 4.88$$

(b) pH = 7.00 because it is the salt of a strong acid and a strong base.
(c) pH = 7.00 because it is the salt of a strong acid and a strong base.
(d) Given: $[NH_4HSO_4(aq)] = 2.61$ mol/L; $K_b = 1.8 \times 10^{-5}$
Required: pH
Analysis:

$HSO_4^-(aq)$ + $H_2O(aq)$	$\rightleftharpoons$	$SO_4^{2-}(aq)$ + $H^+(aq)$
2.61	—	0	0
$-x$	—	$+x$	$+x$
$2.61 - x$	—	x	x

$$K_a = 1.2 \times 10^{-2}$$

$$K_a = \frac{[SO_4^-(aq)][H^+(aq)]}{[HSO_4^{2-}(aq)]}$$

Solution:

$$1.2 \times 10^{-2} = \frac{(x)(x)}{(2.61 - x)}$$

$$1.2 \times 10^{-2}(2.61 - x) = x^2$$

$$0 = x^2 + (0.012)x - 0.03132$$

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$= \frac{-0.012 \pm \sqrt{(0.012)^2 + 4(0.0313)}}{2}$$

$$= 0.171$$

$$x = [H^+(aq)]$$

$$= 0.171 \text{ mol/L}$$

$$pH = -\log(0.171)$$

$$pH = 0.767$$

(e) Given: $[NaC_2H_3O_2(aq)] = 2.80$ mol/L; $K_a = 1.8 \times 10^{-5}$
Required: pH
Analysis:

$C_2H_3O_2^-(aq)$	+ $H_2O(l)$ $\rightleftharpoons$	$HC_2H_3O_2(aq)$	+ $OH^-(aq)$
2.80	−	0	0
$-x$	−	$+x$	$+x$
$2.80 - x$	−	x	x

$$K_b = \frac{K_w}{K_a}$$

$$K_b = \frac{1 \times 10^{-14}}{1.8 \times 10^{-5}}$$

$$K_b = 5.55 \times 10^{-10}$$

$$K_b = \frac{[HC_2H_3O_2(aq))][OH^-(aq)]}{[C_2H_3O_2^-(aq)]}$$

Solution:

$$5.55 \times 10^{-10} = \frac{(x)(x)}{(2.80 - x)}$$

$$5.55 \times 10^{-10} \approx \frac{(x)(x)}{2.80}$$

$$x^2 \approx 1.554 \times 10^{-9}$$

$$x = [OH^-(aq)]$$

$$\approx 3.92 \times 10^{-5} \text{ mol/L}$$

$pOH = -\log(3.92 \times 10^{-5})$
$pOH = 4.40$
$pH = 14.0 - 4.40$
$pH = 9.60$

(f) Given: [NaClO(aq)] = 0.91 mol/L; $K_a = 3.5 \times 10^{-8}$
Required: pH
Analysis:

$ClO^-(aq)$ + $H_2O(l)$ $\rightleftharpoons$	$HClO\,(aq)$ +	$OH^-(aq)$
0.91 −	0	0
$-x$ −	$+x$	$+x$
$0.91 - x$ −	x	x

$$K_b = \frac{K_w}{K_a}$$

$$K_b = \frac{1\times10^{-14}}{3.5\times10^{-8}}$$

$$K_b = 2.86 \times 10^{-7}$$

$$K_b = \frac{[HClO(aq))][OH^-(aq)]}{[ClO^-(aq)]}$$

Solution:

$$2.86 \times 10^{-7} = \frac{(x)(x)}{(0.91 - x)}$$

$$2.86 \times 10^{-7} \approx \frac{(x)(x)}{0.91}$$

$$x^2 \approx 2.602\times10^{-7}$$

$$x = [OH^-(aq)]$$

$$\approx 5.10 \times 10^{-4}\ \text{mol/L}$$

$pOH = -\log(5.10 \times 10^{-4})$
$pOH = 3.29$
$pH = 14.0 - 3.29$
$pH = 10.71$

5. (a) Given: $[C_6H_5NH_3Cl(aq)] = 0.10$ mol/L; $K_b = 4.1 \times 10^{-10}$
Required: pH
Analysis:

$C_6H_5NH_3^+(aq)$ $\rightleftharpoons$	$C_6H_5NH_2(aq)$ +	$H^+(aq)$
0.10	0	0
$-x$	$+x$	$+x$
$0.10 - x$	x	x

$$K_a = \frac{K_w}{K_b}$$

$$K_a = \frac{1 \times 10^{-14}}{4.1 \times 10^{-10}}$$

$$K_a = 2.44 \times 10^{-5}$$

$$K_a = \frac{[C_6H_5NH_2(aq)][H^+(aq)]}{[C_6H_5NH_3^+(aq)]}$$

Solution: $2.44 \times 10^{-4} = \frac{(x)(x)}{(0.10 - x)}$ 2.44×10^{-5}

$$2.44 \times 10^{-4} \approx \frac{(x)(x)}{0.10} \qquad 2.44 \times 10^{-5}$$

$$x^2 \approx 2.44 \times 10^{-6}$$

$x = [H^+(aq)]$ 1.56×10^{-3} mol/L

$pH = -\log 1.56 \times 10^{-3})$

$pH = 2.81$

(b) A solution of calcium oxide is basic, and a solution of nitrogen oxide is neutral; so calcium oxide would be better to neutralize aniline hydrochloride.

(c) The oxide is a weak base; so it is easier to control the neutralization with the oxide than with sodium hydroxide. Hydrochloric acid cannot be used to neutralize an acid.

6. (a) $Zn(s) + O_2(g) \rightarrow ZnO(s)$
$ZnO(s) + H_2O(l) \rightleftharpoons Zn^{2+}(s) + 2\ OH^-(aq)$

$C(s) + O_2(g) \rightarrow CO_2(g)$
$CO_2(g) + H_2O(l) \rightleftharpoons H^+(aq) + HCO_3^-(aq)$

$P_4(s) + 5\ O_2(g) \rightarrow P_4O_{10}(s)$
$P_4O_{10}(s) + 6\ H_2O(l) \rightleftharpoons 4\ H_3PO_4(aq)$
$H_3PO_4(aq) \rightleftharpoons H^+(aq) + H_2PO_4^-(aq)$

$Fe(s) + O_2(g) \rightarrow Fe_2O_3(s)$
$Fe_2O_3(s) + 3\ H_2O(l) \rightleftharpoons Fe^{3+}(aq) + 6\ OH^-(aq)$

(b)

Element	Predicted Color
Zn	blue
C	pink
P	pink
Fe	blue

7. (a) Optimum pH is about 8.2.
(b) Answers may vary. Sample answer: Calcium carbonate and sodium ethanoate could be used because they are a weak base and a weak acid respectively and are not toxic.
(c) Answers may vary. Sample answer: pH can change as carbon dioxide is absorbed from the air and as the organism produces compounds that affect pH. The pH can be adjusted by adding acidic or basic substances.