Section 8.5: Calculations Involving Basic Solutions

Tutorial 1 Practice, page 527

1. Given: [KOH (aq)] = 0.00100 mol/L

Required: $[H^+(aq)]$, $[OH^-(aq)]$

Analysis: $[OH^-(aq)]$ = 0.00100 mol/L because KOH is a strong base.

$$[H^+] = \frac{1.0\times10^{-14}}{[OH^-(aq)]}$$

Solution: $$[H^+] = \frac{1.0\times10^{-14}}{0.00100}$$

$[H^+(aq)] = 1.00 \times 10^{-11}$ mol/L

$[OH^-(aq)] = 1.00 \times 10^{-3}$ mol/L

2. Given: $[Sr(OH)_2(aq)]$ = 0.042 mol/2.00L = 0.021 mol/L

Required: pH

Analysis: $[OH^-(aq)]$ = 0.042 mol/L because $Sr(OH)_2$ is a strong base producing 2 mol OH^- per mole of compound

Solution: pOH = −log$[OH^-(aq)]$

= −log(0.042) = 1.688

pOH = 1.377

pH = 14.00 − pOH

pH = 12.64

Tutorial 2 Practice, page 529

1. (a) From table, K_b $(C_2H_3O_2^-) = 5.6 \times 10^{-10}$

(b) From table, K_a $(H_3BO_3) = 5.8 \times 10^{-10}$

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

$$K_b = \frac{1.0\times10^{-14}}{5.8\times10^{-10}}$$

$K_b = 1.7 \times 10^{-5}$

2. Given: [base] = 0.20 mol/L; $K_b = 3.82 \times 10^{-10}$

Required: pH

Analysis:

	base(aq)	$\rightleftharpoons$	$base^+(aq)$	+	$OH^-(aq)$
I	0.20		0		0
C	$-x$		$+x$		$+x$
E	$0.20 - x$		x		x

$$K_b = \frac{[base^+(aq)][OH^-(aq)]}{[base(aq)]}$$

Solution: $3.82 \times 10^{-10} = \frac{(x)(x)}{(0.20 - x)}$

$$3.82 \times 10^{-10} \approx \frac{(x)(x)}{0.20}$$

$$x^2 \approx 7.64 \times 10^{-9}$$

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

$$\approx 8.74 \times 10^{-5} \text{ mol/L}$$

pOH = $-\log(8.74 \times 10^{-5})$

pOH = 4.06

pH = 14.00 – 4.06

pH = 8.94

3. Given: $[N_2H_4]$ = 4.5 mol/L; $K_b = 1.7 \times 10^{-6}$

Required: pH

Analysis:

	$N_2H_4(aq)$	+ $H_2O(l)$ $\rightleftharpoons$	$N_2H_5^+(aq)$	+ $OH^-(aq)$
I	4.5	–	0	0
C	$-x$	–	$+x$	$+x$
E	$4.5 - x$	–	x	x

$$K_b = \frac{[N_2H_5^+(aq)][OH^-(aq)]}{[N_2H_4(aq)]}$$

Solution: $1.7 \times 10^{-6} = \frac{(x)(x)}{(4.5 - x)}$

$$1.7 \times 10^{-6} \approx \frac{(x)(x)}{4.5}$$

$$x^2 \approx 7.65 \times 10^{-6}$$

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

$$\approx 2.77 \times 10^{-3} \text{ mol/L}$$

pOH = $-\log(2.77 \times 10^{-3})$

pOH = 2.56

pH = 14.00 – 2.56

pH = 11.44

Section 8.5 Questions, page 530

1. (a) Given: [NaOH (aq)] = 0.00300 mol/L

Required: pH

Analysis: $[OH^-(aq)]$ = 0.00300 mol/L because KOH is a strong base.

Solution: $pOH = -\log[OH^-(aq)]$

$= -\log(0.00300) = 2.523$

$pH = 14.000 - pOH$

$= 14.000 - 2.523$

$pH = 11.477$

(b) Given: $[Ba(OH)_2(aq)]$ = 0.0020 mol/L

Required: pH

Analysis: $[OH^-(aq)]$ = 0.0040 mol/L because $Ba(OH)_2$ is a strong base producing 2 mol OH^- per mole of compound

Solution: $pOH = -\log[OH^-(aq)]$

$= -\log(0.0040) = 2.40$

$pOH = 2.40$

$pH = 14.00 - pOH$

$pH = 11.60$

(c) Given: $[CH_3NH_2(aq)]$ = 0.010 mol/L; $K_b = 9.6 \times 10^{-4}$

Required: pH

Analysis:

	$CH_3NH_2(aq)$ $\rightleftharpoons$	$CH_3NH_3^+(aq)$ +	$OH^-(aq)$
I	0.010	0	0
C	$-x$	$+x$	$+x$
E	$0.010 - x$	x	x

$$K_b = \frac{[CH_3NH_3^+(aq)][OH^-(aq)]}{[CH_3NH_2(aq)]}$$

Solution:

$$9.6 \times 10^{-4} = \frac{(x)(x)}{(0.010 - x)}$$

$$9.6 \times 10^{-4} \approx \frac{(x)(x)}{0.010}$$

$$x^2 \approx 9.6 \times 10^{-6}$$

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

$$\approx 3.10 \times 10^{-3} \text{ mol/L}$$

$pOH = -\log(3.10 \times 10^{-3})$

$pOH = 2.51$

$pH = 14.00 - 2.51$

$pH = 11.49$

(d) Given: $[N_2H_4]$ = 0.0250 mol/L; $K_b = 1.7 \times 10^{-6}$
Required: pH
Analysis:

	$N_2H_4(aq)$ + $H_2O(l)$ $\rightleftharpoons$		$N_2H_5^+(aq)$ +	$OH^-(aq)$
I	0.0250	−	0	0
C	$-x$	−	$+x$	$+x$
E	$0.0250 - x$	−	x	x

$$K_b = \frac{[N_2H_5^+(aq)][OH^-(aq)]}{[N_2H_4(aq)]}$$

Solution: $1.7 \times 10^{-6} = \dfrac{(x)(x)}{(0.0250 - x)}$

$$1.7 \times 10^{-6} \approx \frac{(x)(x)}{0.0250}$$
$$x^2 \approx 4.25 \times 10^{-8}$$
$$x = [OH^-(aq)]$$
$$\approx 2.06 \times 10^{-4} \text{ mol/L}$$

$pOH = -\log(2.06 \times 10^{-4})$
$pOH = 3.69$
$pH = 14.00 - 3.69$
$pH = 10.31$

2. (a) From table, K_a (H_2S) = 1.1×10^{-7}

$$K_b = \frac{K_w}{K_a}$$
$$K_b = \frac{1.0 \times 10^{-14}}{1.1 \times 10^{-7}}$$
$K_b = 9.1 \times 10^{-8}$

(b) $K_a = 7.2 \times 10^{-4}$

$$K_b = \frac{K_w}{K_a}$$
$$K_b = \frac{1.0 \times 10^{-14}}{7.2 \times 10^{-4}}$$
$K_b = 1.4 \times 10^{-11}$

(c) From table, K_a (HCN) = 6.2×10^{-10}

$$K_b = \frac{K_w}{K_a}$$
$$K_b = \frac{1.0 \times 10^{-14}}{6.2 \times 10^{-10}}$$
$K_b = 1.6 \times 10^{-5}$

(d) From table, K_a (HF) = 6.6×10^{-4}

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

$$K_b = \frac{1.0 \times 10^{-14}}{6.6 \times 10^{-4}}$$

$K_b = 1.5 \times 10^{-11}$

3. (a) Given: $[C_{17}H_{19}NO_3(aq)] = 0.01$ mol/L; $K_b = 7.5 \times 10^{-7}$

Required: pH

Analysis:

	$C_{17}H_{19}NO_3(aq)$	+ $H_2O(l)$ $\rightleftharpoons$	$C_{17}H_{20}NO_3^+(aq)$	+ $OH^-(aq)$
I	0.01	–	0	0
C	$-x$	–	$+x$	$+x$
E	$0.01 - x$	–	x	x

$$K_b = \frac{[C_{17}H_{20}NO_3^+(aq)][OH^-(aq)]}{[C_{17}H_{19}NO_3(aq)]}$$

Solution: $7.5 \times 10^{-7} = \frac{(x)(x)}{(0.01 - x)}$

$$7.5 \times 10^{-7} \approx \frac{(x)(x)}{0.01}$$

$x^2 \approx 7.5 \times 10^{-9}$

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

$\approx 8.7 \times 10^{-5}$ mol/L

pOH = $-\log(8.7 \times 10^{-5})$

pOH = 4.06

pH = 14.00 – 4.06

pH = 9.94

(b) Given: $[C_{21}H_{22}N_2O_2(aq)] = 0.001$ mol/L; $K_b = 1.0 \times 10^{-6}$

Required: pH

Analysis:

	$C_{21}H_{22}N_2O_2(aq)$	+ $H_2O(l)$ $\rightleftharpoons$	$C_{21}H_{23}N_2O_2^+(aq)$	+ $OH^-(aq)$
I	0.001	–	0	0
C	$-x$	–	$+x$	$+x$
E	$0.001 - x$	–	x	x

$$K_b = \frac{[C_{21}H_{23}N_2O_2^+(aq)][OH^-(aq)]}{[C_{21}H_{22}N_2O_2(aq)]}$$

Solution: $1.0 \times 10^{-6} = \dfrac{(x)(x)}{(0.001 - x)}$

$$1.0 \times 10^{-6} \approx \frac{(x)(x)}{0.001}$$

$$x^2 \approx 1.0 \times 10^{-9}$$

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

$$\approx 3.2 \times 10^{-5} \text{ mol/L}$$

$pOH = -\log(3.2 \times 10^{-5})$

$pOH = 4.50$

$pH = 14.00 - 4.50$

$pH = 9.50$

4. (a) Given: ($[(C_2H_5)_3N(aq)] = 0.20$ mol/L; $K_b = 4.0 \times 10^{-4}$

Required: $[H^+(aq)]$, $[OH^-(aq)]$, pH

Analysis:

	$(C_2H_5)_3N(aq)$	+ $H_2O(l)$ $\rightleftharpoons$	$(C_2H_5)_3NH^+(aq)$	+ $OH^-(aq)$
I	0.20	–	0	0
C	$-x$	–	$+x$	$+x$
E	$0.20 - x$	–	x	x

$$K_b = \frac{[(C_2H_5)_3NH^+(aq)][OH^-(aq)]}{[(C_2H_5)_3N(aq)]}$$

Solution: $4.0 \times 10^{-4} = \dfrac{(x)(x)}{(0.20 - x)}$

$$4.0 \times 10^{-4} \approx \frac{(x)(x)}{0.20}$$

$$x^2 \approx 8.00 \times 10^{-5}$$

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

$$\approx 8.94 \times 10^{-3} \text{ mol/L}$$

$[H^+(aq)]\,[OH^-(aq)] = 1.0 \times 10^{-14}$

$[H^+(aq)] = \dfrac{1.0 \times 10^{-14}}{8.94 \times 10^{-3}}$

$[H^+(aq)] = 1.12 \times 10^{-11}$ mol/L

$pH = -\log(1.12 \times 10^{-11})$

$= 11.95$

Statement: $[OH^-(aq)] = 8.9 \times 10^{-3}$ mol/L; $[H^+(aq)] = 1.1 \times 10^{-11}$ mol/L; pH = 11.95

(b) Given: $[HONH_2(aq)] = 0.20$ mol/L; $K_b = 1.1 \times 10^{-8}$

Required: $[H^+(aq)]$, $[OH^-(aq)]$, pH

Analysis:

	$HONH_2(aq)$ $\rightleftharpoons$	$NH_2^+(aq)$ +	$OH^-(aq)$
I	0.20	0	0
C	$-x$	$+x$	$+x$
E	$0.20 - x$	x	x

$$K_b = \frac{[NH_2^+(aq)][OH^-(aq)]}{[HONH_2(aq)]}$$

Solution: $$1.1 \times 10^{-8} = \frac{(x)(x)}{(0.20 - x)}$$

$$1.1 \times 10^{-8} \approx \frac{(x)(x)}{0.20}$$

$$x^2 \approx 2.2 \times 10^{-9}$$

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

$$\approx 4.7 \times 10^{-5} \text{ mol/L}$$

$$[H^+(aq)]\,[OH^-(aq)] = 1.0 \times 10^{-14}$$

$$[H^+(aq)] = \frac{1.0 \times 10^{-14}}{4.7 \times 10^{-5}}$$

$$[H^+(aq)] = 2.1 \times 10^{-10} \text{ mol/L}$$

$$pH = -\log(2.1 \times 10^{-10})$$

$$= 9.67$$

Statement: $[OH^-(aq)] = 4.7 \times 10^{-5}$ mol/L; $[H^+(aq)] = 2.1 \times 10^{-10}$ mol/L; pH = 9.7

5. Given: $[Ca(OH)_2] = 0.00040$ mol/L; $K_b = 5.0 \times 10^{-11}$

Required: $[OH^-(aq)]$, pOH, pH

Solution:

$[OH^-(aq)] = 0.00080$ mol/L because $Ca(OH)_2$ is a strong base.

pOH = −log(0.00080)

= 3.10

pH = 14.00 – 3.10

pH = 10.90

Statement: $[OH^-(aq)] = 0.00080$ mol/L; pOH = 3.10; pH = 10.90

6. (a) Given: [KOH] = 25 g/L

Required: $[OH^-(aq)]$, pOH, pH

Solution: $\dfrac{25\ \cancel{g}}{L} \times \dfrac{1\ mol}{56.0\ \cancel{g}} = 0.45\ mol/L$

$[OH^-(aq)] = 0.45$ mol/L because KOH is a strong base.

$pOH = -\log(0.45)$
$= 0.35$
$pH = 14.00 - 0.35$
$pH = 13.65$

Statement: $[OH^-(aq)] = 0.45$ mol/L; pOH = 0.35; pH = 13.65

(b) Given: [NaOH] = 150.0 g/L

Required: $[OH^-(aq)]$, pOH, pH

Solution: $\dfrac{150.0\ \cancel{g}}{L} \times \dfrac{1\ mol}{40.00\ \cancel{g}} = 3.75\ mol/L$

$[OH^-(aq)] = 3.75$ mol/L because NaOH is a strong base.

$pOH = -\log(3.75)$
$= -0.57$
$pH = 14.00 - (-0.57)$
$pH = 14.57$

Statement: $[OH^-(aq)] = 3.75$ mol/L; pOH = −0.57; pH = 14.57

7. Given: pH = 11.80; $K_b = 1.8 \times 10^{-5}$

Required: $[NH_3(aq)]$

Analysis: $NH_3(aq) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$

Solution:

$pOH = 14.00 - 11.80 = 2.20$
$[OH^-(aq)] = 10^{-2.20}$
$[OH^-(aq)] = 6.3 \times 10^{-3}$ mol/L

$$K_b = \frac{[NH_4^+(aq)][OH^-(aq)]}{[NH_3(aq)]}$$

$$1.8 \times 10^{-5} = \frac{(6.3 \times 10^{-3})(6.3 \times 10^{-3})}{[NH_3(aq)]}$$

$$[NH_3(aq)] = \frac{(6.3 \times 10^{-3})(6.3 \times 10^{-3})}{1.8 \times 10^{-5}}$$

$[NH_3] = 2.2$ mol/L

8. Answers will vary. Sample answer: Use chemical safety goggles and/or a full face shield where splashing is possible. Wear protective clothing, including gloves, lab coat, or apron. Work in fume hood.

9. (a) $K_b = \frac{[HCO_2H(aq)][OH^-(aq)]}{[HCO_2^-(aq)]}$

(b) $K_a = \frac{[HCO_2^-(aq)][H^+(aq)]}{[HCO_2H(aq)]}$

(c) $K_b \times K_a = \frac{\cancel{[HCO_2H(aq)]}[OH^-(aq)]}{\cancel{[HCO_2^-(aq)]}} \times \frac{\cancel{[HCO_2^-(aq)]}[H^+(aq)]}{\cancel{[HCO_2H(aq)]}}$

$K_b \times K_a = \frac{[OH^-(aq)]}{1} \times \frac{[H^+(aq)]}{1} = K_w$

10. (a) Given: pH = 11.2; $K_b = 4.4 \times 10^{-4}$

Required: $[CH_3NH_2(aq)]$

Analysis: $CH_3NH_2(aq) + H_2O(l) \rightleftharpoons CH_3NH_3^+(aq) + OH^-(aq)$

Solution:

pOH = 14.00 − 11.20 = 2.80

$[OH^-(aq)] = 10^{-2.80}$

$[OH^-(aq)] = 1.6 \times 10^{-3}$ mol/L

$$K_b = \frac{[NH_4^+(aq)][OH^-(aq)]}{[NH_3(aq)]}$$

$$4.4 \times 10^{-4} = \frac{(1.6 \times 10^{-3})(1.6 \times 10^{-3})}{[CH_3NH_2(aq)]}$$

$$[CH_3NH_2(aq)] = \frac{(1.6 \times 10^{-3})(1.6 \times 10^{-3})}{4.4 \times 10^{-4}}$$

$[CH_3NH_2]$ = 0.0058 mol/L; this is not the correct concentration.

(b) The solution is too dilute.

(c) Answers may vary. Sample answer: A Coast Guard cocktail is a combination of drugs, including ephedrine that is used to prevent seasickness. The ephedrine prevents the drowsiness that is a side effect of the other drug. It is not now generally used because ephedrine can cause nausea, insomnia, confusion, and occasionally hypertension.