Chapter 14

14.34 ~~14.32~~ (a) X^-, Y^-, Z^- (b) HX < HZ < HY (c) HY

(d) HX (e) $(2/10) \times 100\% = 20\%$

14.35 ~~14.33~~ (C) represents a solution of a weak diprotic acid H_2A. Because K_{a_2} is always less than K_{a_1}, (a) + (d) represent impossible situations. (b) contains no H_2A

14.37 ~~14.35~~ (a) The weakest acid has the strongest conjugate base. HY is the weakest acid because it is the least dissociated. Therefore Y^- has the largest K_b.

(b) The strongest acid has the weakest conjugate base. HX is the strongest acid because it is the most dissociated. Therefore, X^- is the weakest base

14.46 ~~14.44~~ (a) SO_4^{2-} (b) HSO_3^- (c) HPO_4^{2-} (d) NH_3 (e) OH^- (f) NH_2^-

14.47 ~~14.45~~ (a) HSO_3^- (b) H_3O^+ (c) $CH_3NH_3^+$ (d) H_2O (e) H_2CO_3 (f) H_2

14.49 ~~14.47~~ (a) $CN^-(aq) + H_2O(l) \rightleftharpoons HCN(aq) + OH^-(aq)$

base acid acid base

(b) $H_2PO_4^-(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + HPO_4^{2-}(aq)$

acid base acid base

14.49

~~14.47~~ cont. (c) $HPO_4^{2-}(aq) + H_2O(l) \rightleftharpoons H_2PO_4^-(aq) + OH^-(aq)$

base, acid, acid, base

(d) $NH_4^+(aq) + NO_2^-(aq) \rightleftharpoons HNO_2(aq) + NH_3(aq)$

acid, base, acid, base

14.50

~~14.48~~ Strong Acids: HNO_3 + H_2SO_4 ; Strong Bases: H^- + O^{2-}
from data table 14.1

14.54

~~14.52~~ If $[H_3O^+] > 1\times10^{-7}$ M ; soln. is acidic
$[H_3O^+] < 1\times10^{-7}$ M ; soln is basic
$[H_3O^+] = [OH^-] = 1\times10^{-7}$ M ; soln. is neutral
$[OH^-] > 1\times10^{-7}$ M ; soln is basic
$[OH^-] < 1\times10^{-7}$ M ; soln is acidic

(a) $[OH^-] = \frac{K_w}{[H_3O^+]} = \frac{1\times10^{-14}}{3.4\times10^{-9}} = 2.9\times10^{-6}$ M , basic

(b) $[H_3O^+] = \frac{K_w}{[OH^-]} = \frac{1\times10^{-14}}{0.01} = 1\times10^{-12}$ M , basic

(c) $[H_3O^+] = 1\times10^{-4}$ M , acidic

(d) $[OH^-] = 1.0\times10^{-7}$ M, neutral

(e) $[OH^-] = 1.2\times10^{-10}$ M, acidic

$[OH^-] = K_w/[H_3O^+]$ & $[H_3O^+] = K_w/[OH^-]$

14.55 ~~14.53~~ (a) $[OH^-] = 4 \times 10^{-11}$ M, acidic

(b) $[OH^-] = 5.0 \times 10^{-15}$ M, acidic

(c) $[H_3O^+] = 1.8 \times 10^{-6}$ M, acidic

(d) $[H_3O^+] = 6.7 \times 10^{-12}$ M, basic

(e) $[H_3O^+] = 1.0 \times 10^{-7}$ M, neutral

14.61 ~~14.57~~ $[H_3O^+] = 10^{-pH}$

(a) 1×10^{-9} M (b) 1.0×10^{-7} M (c) 2 M

(d) 6.6×10^{-16} M (e) 2.3×10^{-7} M (f) 1.75×10^{-11} M

14.67

~~14.65~~ (c) Na_2O, $61.98\ g\,mol^{-1}$; 100 mL

moles $Na_2O \Rightarrow 0.20\,g\,Na_2O \times \frac{1\,mol\,Na_2O}{61.98\,g\,Na_2O} = 0.0032\,mol\,Na_2O$

$O^{2-}(aq) + H_2O \xrightarrow{100\%} 2\,OH^-(aq)$

moles $OH^- = 2(0.0032\,mol) = 0.0064\,mol$

$[OH^-] = \frac{0.0064\,mol}{0.1\,L} = 0.064\,M$

$[H_3O^+] = K_w/[OH^-] = 1\times10^{-14}/0.064 = 1.6\times10^{-13}\,M$

$pH = -\log[H_3O^+] = -\log(1.6\times10^{-13}) = 12.80$

1467

~~14.65~~ cont.

(b)

molarity HNO_3 ⇒ $1.26g\ HNO_3 \times \frac{1\ mol\ HNO_3}{63.01g} \times \frac{1}{0.5L} =$

0.0400M

$pH = -\log[H_3O^+] = -\log(0.0400M) = 1.398$

(c) $[OH^-] = 2(0.075M) = 0.15M$

$M_2V_2 = M_1V_1 \qquad M_2 = \frac{M_1V_1}{V_2} = \frac{(0.15)(40mL)}{300mL} = 0.021$

$[H_3O^+] = K_w/[OH^-] = \frac{1\times10^{-14}}{0.02} = 5.0\times10^{-13}M$

(d) Mixing equal volumes of the two strong Acids results in cutting both conc. in half.

$[H_3O^+] = 0.10M + 0.25M = 0.35M$

$pH = -\log[H_3O^+] = -\log(0.35) = \underline{0.46}$

✓ 14.70 $HOBr(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + OBr^-(aq)$

	$HOBr$	H_3O^+	OBr^-
start	0.040 M	—	—
Δ	−x	+x	+x
equil.	0.040 − x	x	x

$$x = [H_3O^+] = 10^{-pH} = 10^{-5.05} = 8.9 \times 10^{-6} M$$

$$K_a = \frac{[H_3O^+][OBr^-]}{[HOBr]} = \frac{x^2}{0.040 - x} = \frac{(8.9 \times 10^{-6})^2}{0.04 - (8.9 \times 10^{-6})} = 2.0 \times 10^{-9}$$

✓

14.71 $C_3H_6O_3(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + C_3H_5O_3^-(aq$

start	0.10	—	—
Δ	− x	+ x	+ x
equil.	0.10 − x	x	x

$x = [H_3O^+] = 10^{-pH} = 10^{-2.43} = 3.7 \times 10^{-3}$ M

$[C_3H_5O_3^-] = 3.7 \times 10^{-3}$ M ; $[C_3H_6O_3] = 0.10 - x =$
$0.10 - 3.7 \times 10^{-3}$ M $= 0.1($

$$K_a = \frac{[H_3O^+][C_3H_5O_3^-]}{[C_3H_6O_3]} = \frac{(3.7 \times 10^{-3})^2}{(0.10 - 3.7 \times 10^{-3})} = 1.4 \times 10^{-4}$$

$pK_a = -\log K_a = -\log(1.4 \times 10^{-4}) = 3.85$

14.74 $HNO_2(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + NO_2^-(aq)$

	HNO_2	H_3O^+	NO_2^-
start	1.5	—	—
Δ	−x	+x	+x
equil.	1.5 − x	x	x

$$K_a = \frac{[H_3O^+][NO_2^-]}{[HNO_2]} = 4.5\times10^{-4} = \frac{x^2}{1.5-x} \approx \frac{x^2}{1.5}$$

$$x = 0.026M = [H_3O^+] = [NO_2^-]$$

$$pH = -\log[H_3O^+] = -\log(0.026M) = 1.59$$

$$\%\text{ dissociation} = \frac{[NO_2^-]}{[HNO_2]_i}\times100 = \frac{0.026}{1.5}\times100 = 1.7\%$$

14.82

(a) $(CH_3)NH(aq) + H_2O(l) \rightleftharpoons (CH_3)_2NH_2^+(aq) + OH^-(aq)$

$$K_b = \frac{[(CH_3)_2NH_2^+][OH^-]}{[(CH_3)_2NH]}$$

(b) $C_6H_5NH_2(aq) + H_2O(l) \rightleftharpoons C_6H_5NH_3^+(aq) + OH^-(aq)$

$$K_b = \frac{[C_6H_5NH_3^+][OH^-]}{[C_6H_5NH_2]}$$

14.82 cont.

(c) $CN^-(aq) + H_2O(l) \rightleftharpoons HCN(aq) + OH^-(aq)$

$$K_b = \frac{[HCN][OH^-]}{[CN^-]}$$

14.84 $[H_3O^+] = 10^{-pH} = 10^{-9.5} = 3.16 \times 10^{-10}\ M$

$$[OH^-] = \frac{K_w}{[H_3O^+]} = \frac{1 \times 10^{-14}}{3.16 \times 10^{-10}} = 3.16 \times 10^{-5}\ M$$

	$C_{17}H_{19}NO_3(aq)$ + $H_2O(l)$ ⇌	$C_{17}H_{20}NO_3^+(aq)$ +	$OH^-(aq)$
start	7.0×10^{-4}	–	–
Δ	$-x$	$+x$	$+x$
equil.	$7.0 \times 10^{-4} - x$	x	x

$x = [OH^-] = 3.16 \times 10^{-5}\ M$

$$K_b = \frac{[C_{17}H_{20}NO_3^+][OH^-]}{[C_{17}H_{19}NO_3]} = \frac{x^2}{7.0 \times 10^{-4} - x} = \frac{(3.16 \times 10^{-5})^2}{(7.0 \times 10^{-4}) - (3.16 \times 10^{-5})}$$

$$= 1.49 \times 10^{-6}$$

$pK_b = -\log K_b = -\log(1.49 \times 10^{-6}\ M) = \underline{5.8}$

14.93 (a) $Fe(NO_3)_3$; Fe^{+3} acidic cation ; NO_3^- neutral anion
soln is acidic

(b) $Ba(NO_3)_2$: Ba^{+2}, neutral cation ; NO_3^- neutral anion
soln is neutral

(c) NaOCl : Na^+, neutral cation ; OCl^- basic anion
soln is basic

(d) NH_4I : NH_4^+, acidic cation ; I^- neutral anion,
soln is acidic

(e) NH_4NO_2 : for NH_4^+ ; $K_a = 5.6 \times 10^{-10}$; for NO_2^-
$K_b = 2.2 \times 10^{-11}$
since $K_a > K_b$; the soln is acidic

(f) $(CH_3NH_3)Cl$, $CH_3NH_3^+$ is acidic cation ; Cl^-
is a neutral anion ; soln is acidic

14.94

(a) $(C_2H_5NH_3)NO_3$: $C_2H_5NH_3^+$, acidic cation ; NO_3^- neutral anion

$C_2H_5NH_3^+$, $K_b = 6.4 \times 10^{-4}$ $\quad$ $C_2H_5NH_3^+$; $K_a = \frac{K_w}{K_b} =$

$$\frac{1.0 \times 10^{-14}}{6.4 \times 10^{-4}} = 1.56 \times 10^{-11}$$

$$C_2H_5NH_3^+(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + C_2H_5NH_2(aq)$$

	$C_2H_5NH_3^+$	H_3O^+	$C_2H_5NH_2$
start	0.1	–	–
Δ	−x	+x	+x
equil.	0.1−x	x	x

$$K_a = \frac{[H_3O^+][C_2H_5NH_2]}{[C_2H_5NH_3^+]} = 1.56 \times 10^{-11} = \frac{x^2}{0.1-x} \approx \frac{x^2}{0.1}$$

solve for x → $x = 1.25 \times 10^{-6}\,M = [H_3O^+] = [C_2H_5NH_2]$

$pH = -\log[H_3O^+] = 5.90$

$[C_2H_5NH_3^+] = 0.1 - x = 0.10M$; $[NO_3^-] = 0.1M$

$$[OH^-] = \frac{K_w}{[H_3O^+]} = \frac{1.0 \times 10^{-14}}{1.25 \times 10^{-6} M} = 8 \times 10^{-9} M$$

14.94 cont. next pg

(b) $Na(CH_3CO_2^-)$: Na^+, neutral cation ; $CH_3CO_2^-$, basic anion

CH_3CO_2H, $K_a = 1.8 \times 10^{-5}$

$CH_3CO_2^-$, $K_b = \frac{K_w}{K_a} = \frac{1 \times 10^{-14}}{1.8 \times 10^{-5}} = 5.6 \times 10^{-10}$

	$CH_3CO_2^-(aq) + H_2O$	$\rightleftharpoons$ $CH_3CO_2H(aq)$	$+ OH^-(aq)$
start	0.1	–	–
Δ	$-x$	$+x$	$+x$
equil.	$0.1-x$	x	x

$$K_b = \frac{[CH_3CO_2H][OH^-]}{[CH_3CO_2^-]} = \frac{x^2}{0.1-x} = 5.6 \times 10^{-10} \approx \frac{x^2}{0.1}$$

$x = 7.5 \times 10^{-6} M = [CH_3CO_2H] = [OH^-]$

$[CH_3CO_2^-] = 0.1 - x = 0.1 M$; $[Na^+] = 0.10 M$

$$[H_3O^+] = \frac{K_w}{[OH^-]} = \frac{1 \times 10^{-14}}{7.5 \times 10^{-6}} = 1.3 \times 10^{-9} M$$

$pH = -\log[H_3O^+] = 8.89$

(c) $NaNO_3$; Na^+ neutral cation & NO_3^- neutral anion

$[Na^+] = [NO_3^-] = 0.1 M$

$[H_3O^+] = [OH^-] = 1 \times 10^{-7} M$, $pH = 7.0$

14.96

(a) $PH_3 < H_2S < HCl$; since electronegativity increases from P to Cl

(b) $NH_3 < PH_3 < AsH_3$; X-H bond strength decreases from N to As (down a group)

(c) $HBrO < HBrO_2 < HBrO_3$; acid strength increases w/ increased # of O atoms.