16.14   (a)   According to the Arrhenius definition, a *base* when dissolved in water increases $[OH^-]$. According to the Brønsted-Lowry theory, a *base* is an H^+ acceptor regardless of physical state. A Brønsted-Lowry base is not limited to aqueous solution and need not contain OH^- or produce it in aqueous solution.

       (b) $NH_3(g) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$ When NH_3 dissolves in water, it accepts H^+ from H_2O (B-L definition). In doing so, OH^- is produced (Arrhenius definition).

            Note that the OH^- produced was originally part of the H_2O molecule, not part of the NH_3 molecule.

16.16   A conjugate acid has one more H^+ than its conjugate base.

       (a)   HCN   (b) OH (c) $H_2PO_4^-$ (d) $C_2H_5NH_3^+$

16.18

	B-L acid	+	B-L base	$\rightleftharpoons$	Conjugate acid	+	Conjugate base
(a)	$HBrO(aq)$		$H_2O(l)$		$H_3O^+(aq)$		$BrO^-(aq)$
(b)	$HSO_4^-(aq)$		$HCO_3^-(aq)$		$H_2CO_3(aq)$		$SO_4^{2-}(aq)$
(c)	$H_3O^+(aq)$		$HSO_3^-(aq)$		$H_2SO_3(aq)$		$H_2O(l)$

16.22 (a) $C_2H_3O_2^-$, weak base; $HC_2H_3O_2$, weak acid

(b) HCO_3^-, weak base; H_2CO_3, weak acid

(c) O_2^-, strong base; OH^-, negligible acid

(d) Cl^-, negligible base; HCl, strong acid

(e) NH_3, weak base; NH_4^+, weak acid

16.44 For a strong acid, which is completely ionized, $[H^+]$ = the initial acid concentration.

(a) $0.00835\ M\ HNO_3 = 0.00835\ M\ H^+$; $pH = -\log(0.00835) = 2.08$

(b) $\dfrac{0.525\ g\ HClO_4}{2.00\ L\ soln} \times \dfrac{1\ mol\ HClO_4}{100.5\ g\ HClO_4} = 2.612 \times 10^{-3} = 2.61 \times 10^{-3}\ M\ HClO_4$

$[H^+] = 2.61 \times 10^{-3}\ M$; $pH = -\log(2.612 \times 10^{-3}) = 2.583$

(c) $M_c \times V_c = M_d \times V_d$; $0.500\ L = 500\ mL$

$1.00\ M\ HCl \times 5.00\ mL\ HCl = M_d\ HCl \times 500\ mL\ HCl$

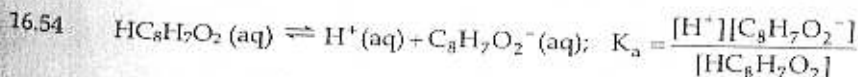$M_d\ HCl = \dfrac{1.00\ M \times 5.00\ mL}{500\ mL} = 1.00 \times 10^{-2}\ M\ HCl = 1.00 \times 10^{-2}\ M\ H^+$

$pH = -\log(1.00 \times 10^{-2}) = 2.000$

(d) $[H^+]_{total} = \dfrac{mol\ H^+\ from\ HCl + mol\ H^+\ from\ HI}{total\ L\ solution}$; $mol = M \times L$

$[H^+]_{total} = \dfrac{(0.020\ M\ HCl \times 0.0500\ L) + (0.010\ M\ HI \times 0.150\ L)}{0.200\ L}$

$[H^+]_{total} = \dfrac{1.0 \times 10^{-3}\ mol\ H^+ + 1.50 \times 10^{-3}\ mol\ H^+}{0.200\ L} = 0.0125 = 0.013\ M$

$pH = -\log(0.0125) = 1.90$

16.54 $HC_8H_7O_2\ (aq) \rightleftharpoons H^+(aq) + C_8H_7O_2^-(aq)$; $K_a = \dfrac{[H^+][C_8H_7O_2^-]}{[HC_8H_7O_2]}$

$[H^+] = [C_8H_7O_2^-] = 10^{-2.68} = 2.09 \times 10^{-3} = 2.1 \times 10^{-3}\ M$

$[HC_8H_7O_2] = 0.085 - 2.09 \times 10^{-3} = 0.0829 = 0.083\ M$

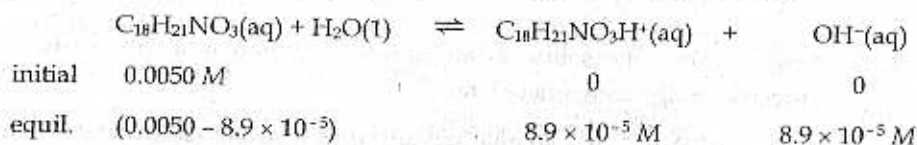$K_a = \dfrac{(2.09 \times 10^{-3})^2}{0.0829} = 5.3 \times 10^{-5}$

16.60

$$HClO(aq) \rightleftharpoons H^+(aq) + ClO^-(aq)$$

initial   0.0075 M 0   0

equil.   (0.0075 − x) M x M x M

$$K_a = \frac{[H^+][ClO^-]}{[HClO]} = \frac{x^2}{(0.0075-x)} \approx \frac{x^2}{0.0075} = 3.0 \times 10^{-5}$$

$x^2 = 0.0075\,(3.0 \times 10^{-8}); \; x = 1.5 \times 10^{-5}\,M = [H^+] = [H_3O^+] = [ClO^-]$

$[HClO] = 7.5 \times 10^{-3} - 1.5 \times 10^{-6} = 7.485 \times 10^{-3} = 7.5 \times 10^{-3}\,M$

Check. $\dfrac{4.7 \times 10^{-5}\,M H^+}{0.0075\,M\,HClO} \times 100 = 0.20\%$ ionization; the assumption is valid

16.78   (a)   pOH = 14.00 − 9.95 = 4.05; $[OH^-] = 10^{-4.05} = 8.91 \times 10^{-6} = 8.9 \times 10^{-5}\,M$

$$C_{18}H_{21}NO_3(aq) + H_2O(l) \rightleftharpoons C_{18}H_{21}NO_3H^+(aq) + OH^-(aq)$$

initial   0.0050 M 0   0

equil.   (0.0050 − 8.9 × 10⁻⁵) $8.9 \times 10^{-5}\,M$ $8.9 \times 10^{-5}\,M$

$$K_b = \frac{[C_{18}H_{21}NO_3H^+][OH^-]}{[C_{18}H_{21}NO_3]} = \frac{(8.91 \times 10^{-5})^2}{(0.0050-8.91 \times 10^{-5})} = 1.62 \times 10^{-5} = 1.6 \times 10^{-6}$$

(b) $pK_b = -\log(K_b) = -\log(1.62 \times 10^{-5}) = 5.79$

16.86   (a)   acidic; Cr^{3+} is a highly charged metal cation and a Lewis acid; Br^- is negligible.

(b)   neutral; both Li^+ and I^- are negligible.

(c)   basic; PO_4^{3-} is the conjugate base of HPO_4^{2-}; K^+ is negligible.

(d)   acidic; $CH_3NH_3^+$ is the conjugate acid of CH_3NH_2; Cl^- is negligible.

(e)   acidic; HSO_4^- is a negligible base, but a fairly strong acid ($K_a = 1.2 \times 10^{-2}$).
            K^+ is negligible.

16.96   (a) NO_2^- (HNO_3 is the stronger acid because it has more nonprotonated O atoms, so NO_2^- is the stronger base.)

(b) PO_4^{3-} (K_a for $HAsO_4^{2-}$ is greater than K_a for HPO_4^{2-}, so K_b for PO_4^{3-} is greater and PO_4^{3-} is the stronger base. Note that P is more electronegative than As and H_3PO_4 is a stronger acid than H_3AsO_4, which could lead to the conclusion that AsO_4^{3-} is the stronger base. As in all cases, the measurement of base strength, K_b, supercedes the prediction. Chemistry is an experimental science.

(c) CO_3^{2-} (The more negative the anion, the stronger the attraction for H^+.)