1. (4 pts) At body temperature (98.6 °F = 37.0 °C), \( K_w \) has the value \( 2.4 \times 10^{-14} \). If the pH of blood is 7.4 under these conditions, what are the concentrations of \( \text{H}_3\text{O}^+ \) and \( \text{OH}^- \)?

\[
\begin{align*}
\text{pH} &= 7.4 \quad \Rightarrow \quad [\text{H}_3\text{O}^+] = 1.0 \times 10^{-7} \\
\text{pOH} &= 13.6 - 7.4 = 6.2 \Rightarrow [\text{OH}^-] = 6.3 \times 10^{-7}
\end{align*}
\]

2. (6 pts) Calculate the pH of a 0.15 M aqueous solution of \( \text{AlCl}_3 \). \( K_a = 1.4 \times 10^{-5} \) for the acid dissociation of the hydrated aluminum ion.

\[
\begin{align*}
\text{Al(H}_2\text{O)}_6^{3+} \text{(aq)} + \text{H}_2\text{O(l)} &\rightleftharpoons [\text{Al(H}_2\text{O)}_5\text{OH}]^{2+} \text{(aq)} + \text{H}_3\text{O}^+ \text{(aq)} \\
0.15 &- x \\
K_a &= 1.4 \times 10^{-5} = \frac{x^2}{0.15 - x} \Rightarrow x = 1.4 \times 10^{-3} = [\text{H}_3\text{O}^+] \\
\text{pH} &= 2.84
\end{align*}
\]

3. (10 pts) Niacin (\( \text{C}_6\text{H}_4\text{NCOOH} \)), abbreviated HNI, is one of the B vitamins and it is an acid.
   a) Write an equation for its equilibrium reaction with water.

\[
\begin{align*}
\text{HNI} + \text{H}_2\text{O} &\rightleftharpoons \text{H}_3\text{O}^+ + \text{NI}^- \\
\text{b) The } K_a &= 1.5 \times 10^{-5} \text{ for niacin. Calculate } K_b \text{ for its conjugate base.} \\
K_b &= \frac{K_w}{K_a} = \frac{1.0 \times 10^{-14}}{1.5 \times 10^{-5}} = 6.7 \times 10^{-10}
\end{align*}
\]
   c) Is the conjugate base of niacin a stronger or weaker base than pyridine, \( \text{C}_5\text{H}_5\text{N} \) (\( pK_b = 8.77 \))?

\[
\begin{align*}
pK_b(\text{HNI}) &= 9.18 \quad ; \quad \text{it is weaker than pyridine}
\end{align*}
\]

4. (10 pts) Citric acid, \( \text{H}_3\text{C}_6\text{H}_5\text{O}_7 \), abbreviated \( \text{H}_3\text{Cl} \), is a triprotic acid with \( K_{a1} = 7.4 \times 10^{-4} \), \( K_{a2} = 1.7 \times 10^{-5} \), and \( K_{a3} = 4.0 \times 10^{-7} \). Calculate the pH of a 0.060 M solution of citric acid. Be careful of your approximations, state each clearly and check each. You don’t have to use the quadratic equation, but it is

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

\[
\begin{align*}
\text{H}_3\text{Cl} + \text{H}_2\text{O} &\rightleftharpoons \text{H}_3\text{O}^+ + \text{H}_2\text{Cl}^- \\
0.060 &- x \\
\text{pH} &= 7.4 \times 10^{-4} = \frac{x^2}{0.060 - x} \Rightarrow x = 0.0063 \\
\text{but } 0.060 - 0.0063 &= 0.053 \\
\Rightarrow x &= 6.3 \times 10^{-3} \\
\text{check} \quad \text{are OK}
\end{align*}
\]

\[
\begin{align*}
\text{H}_2\text{Cl}^- + \text{H}_2\text{O} &\rightleftharpoons \text{H}_3\text{O}^+ + \text{H}_3\text{Cl}^- \\
0.0063 &- x \\
\text{pH} &= \frac{\text{H}_3\text{O}^+}{\text{H}_3\text{Cl}^-} = \frac{0.0063}{0.0063 - x} \\
\Rightarrow x &= 1.7 \times 10^{-5} \\
\text{check } 0.0063 - 0.000017 &= 0.0063
\end{align*}
\]

; above conc. remain unchanged.
1. (4 pts) At body temperature (98.6°F = 37.0°C), $K_w$ has the value $2.4 \times 10^{-14}$. If the pH of blood is 7.4 under these conditions, what are the concentrations of $H_3O^+$ and $OH^-$?

$$pK_w = -\log K_w$$

$$PH = 7.4 \Rightarrow [H_3O^+] = 4.0 \times 10^{-8}$$

$$pOH = 13.6 - 7.4 = 6.2 \Rightarrow [OH^-] = 6.3 \times 10^{-7}$$

2. (6 pts) Boric acid, $B(OH)_3$, is used as a mild antiseptic. What is the pH of a 0.025 M aqueous solution of boric acid ($K_a = 5.9 \times 10^{-10}$)?

$$B(OH)_3(aq) + 3H_2O(l) = B(OH)_4^-(aq) + H_3O^+(aq)$$

$$K_a = \frac{x^2}{0.025 - x} \Rightarrow x = 3.8 \times 10^{-9} \Rightarrow PH = 5.4$$

3. (10 pts) Ephedrine ($C_{10}H_{15}ON$) is a base that is used in nasal sprays as a decongestant.

a) Write an equation for its equilibrium reaction with water.

$$C_{10}H_{15}ON + H_2O \rightleftharpoons C_{10}H_{15}ONH^+ + OH^- \quad \text{(similar to NH}_3\text{)}$$

b) The $K_a$ for ephedrine is $1.4 \times 10^{-4}$. Calculate $K_a$ for its conjugate acid.

$$C_{10}H_{15}ONH^+ + H_2O \rightleftharpoons C_{10}H_{15}ON + H_3O^+ \quad K_a = \frac{K_w}{K_b} = \frac{1.0 \times 10^{-14}}{1.4 \times 10^{-4}} \Rightarrow K_a = 7.1 \times 10^{-11} $$

Is ephedrine a stronger or weaker base than ammonia ($pK_b = 4.74$)?

$$pK_b(Ep) = 3.36 \Rightarrow \text{ephedrine is stronger base than ammonia}$$

4. (10 pts) Phthalic acid ($H_2C_8H_4O_4$), abbreviated $H_2Ph$, is a diprotic acid. Its acid dissociation constants are $K_{a1} = 1.26 \times 10^{-3}$ and $K_{a2} = 3.10 \times 10^{-6}$. If 0.010 mol of phthalic acid is dissolved and diluted to 1.00 liter of solution, calculate the equilibrium concentrations of all species present. Be careful of approximations, state each clearly and check each.

$$H_2Ph + H_2O \rightleftharpoons H_2O^+ + Ph^-$$

$$K_{a1} = 1.26 \times 10^{-3} = \frac{x^2}{0.0100 - x} \Rightarrow x = 3.55 \times 10^{-3}$$

$$[H_2O^+] = 3.00 \times 10^{-3} \Rightarrow [H_2Ph] = 0.00700$$

$$K_{a2} = 3.10 \times 10^{-6} = \left(\frac{3.00 \times 10^{-3} x}{y}\right) \Rightarrow y = 3.00 \times 10^{-3}$$

$$[Ph^2+] = (3.00 \times 10^{-3} + 3.00 \times 10^{-3}) \approx 3.00 \times 10^{-3} \text{ OK}$$

$$[H_2O^+] = 3.10 \times 10^{-6}$$

$$[H_2Ph] = 3.10 \times 10^{-6} \text{ OK}$$

$$[Ph^2+] = 3.10 \times 10^{-6} \text{ OK}$$
1. (4 pts) At body temperature (98.6 °F = 37.0 °C), \( K_w \) has the value \( 2.4 \times 10^{-14} \). If the pH of blood is 7.4 under these conditions, what are the concentrations of \( \text{H}_3\text{O}^+ \) and \( \text{OH}^- \)?

\[
\begin{align*}
\text{pK}_w &= -\log_{10} K_w \\
&= 13.6 \\
\text{pH} &= 7.4 = X \left[ \frac{\text{H}^+}{1} \right] = 4.0 \times 10^{-8} \\
\text{pOH} &= 13.6 - 7.4 = 6.2 \left[ \frac{\text{OH}^-}{1} \right] = 6.3 \times 10^{-7}
\end{align*}
\]

2. (6 pts) Calculate the pH of a 0.15 M aqueous solution of AlCl₃. \( K_a = 1.4 \times 10^{-5} \) for the acid dissociation of the hydrated aluminum ion

\[
\begin{align*}
\text{Al(H}_2\text{O)}_3^{3+} \text{(aq)} + \text{H}_2\text{O(l)} &\rightleftharpoons [\text{Al(H}_2\text{O)}_2\text{OH}]^{2+} \text{(aq)} + \text{H}_3\text{O}^+ \text{(aq)} \\
&\text{O.15} \\
\end{align*}
\]

\[
\begin{align*}
K_a &= 1.4 \times 10^{-5} \\
&= \frac{X^2}{0.15} \\
&= \frac{X^2}{0.15} \\
&= \sqrt{(0.15)(1.4 \times 10^{-5})} = 1.4 \times 10^{-3}M \\
\text{PH} &= 3.8
\end{align*}
\]

3. (10 pts) Niacin (C₆H₄NCOOH), abbreviated HNi, is one of the B vitamins and it is an acid.

a) Write an equation for its equilibrium reaction with water.

\[
\text{H}^+ + \text{Ni}^- + \text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{O}^+ + \text{Ni}^-
\]

b) The \( K_a = 1.5 \times 10^{-5} \) for niacin. Calculate \( K_a \) for its conjugate base.

\[
\begin{align*}
\text{Ni}^- + \text{H}_2\text{O} \rightleftharpoons \text{HNi} + \text{OH}^- \\
K_b &= \frac{K_w}{K_a} = \frac{1.0 \times 10^{-14}}{1.5 \times 10^{-5}} = 6.7 \times 10^{-10}
\end{align*}
\]

c) Is the conjugate base of niacin a stronger or weaker base than pyridine, C₅H₅N \( (K_a = 8.77) \)?

\[
\begin{align*}
\text{p}K_b(Ni^-) &= 9.18 \\
\text{Ni}^- \text{ is a weaker base than pyridine}
\end{align*}
\]

4. (10 pts) Citric acid, \( \text{H}_3\text{C}_6\text{H}_5\text{O}_7 \), abbreviated \( \text{H}_3\text{Ci} \), is a tripotopic acid with \( K_{a1} = 7.4 \times 10^{-4}, K_{a2} = 1.7 \times 10^{-5} \), and \( K_{a3} = 4.0 \times 10^{-7} \). Calculate the pH of a 0.060 M solution of citric acid. Be careful of your approximations, state each clearly and check each. You don't have to use the quadratic equation, but it is \( x = \frac{1}{2}(-b \pm [b^2 - 4ac]^{1/2}) \).

\[
\begin{align*}
\text{H}_3\text{Ci} + \text{H}_2\text{O} &\rightleftharpoons \text{H}_3\text{O}^+ + \text{H}_2\text{Ci}^- \\
0.060 &- x \\
\end{align*}
\]

\[
\begin{align*}
K_{a1} &= 7.4 \times 10^{-4} = \frac{X}{0.060-x} \Rightarrow x = 6.7 \times 10^{-3} \\
\text{and} &0.060 - 6.7 \times 10^{-3} = 0.053 \text{ so use } x \\
7.4 \times 10^{-4} &= \frac{X^2}{0.053} \Rightarrow x = 6.3 \times 10^{-3}
\end{align*}
\]

\[
\begin{align*}
\text{Now } \text{H}_2\text{Ci}^- + \text{H}_2\text{O} &\rightleftharpoons \text{H}_3\text{O}^+ + \text{H}_2\text{Ci}^- \\
6.3 \times 10^{-3} &- x \\
\text{Nominal } 0.060 - 6.3 \times 10^{-3} = 0.054 \text{ OK}
\end{align*}
\]

\[
\begin{align*}
K_{a2} &= 1.7 \times 10^{-5} = \frac{(6.3 \times 10^{-3} + X)(X)}{(6.3 \times 10^{-3} - X)} \Rightarrow X = 6.3 \times 10^{-3} \\
\text{Assuming OK} \\
[\text{H}_2\text{O}^+] = 6.3 \times 10^{-3} + 1.7 \times 10^{-5} = 6.3 \times 10^{-3} \text{ and } \text{PH} = 2.2
\end{align*}
\]
1. (4 pts) At body temperature (98.6 °F = 37.0 °C), $K_w$ has the value $2.4 \times 10^{-14}$. If the pH of blood is 7.4 under these conditions, what are the concentrations of $H_3O^+$ and $OH^-$?

$$\rho K_w = -\log K_w$$
$$= 13.6$$
$$\rho pH = 7.4 \Rightarrow [H_3O^+] = 4.0 \times 10^{-8}$$
$$\rho OH^- = 13.6 - 7.4 = 6.2 \Rightarrow [OH^-] = 6.3 \times 10^{-7}$$

2. (6 pts) Boric acid, $B(OH)_3$, is used as a mild antiseptic. What is the pH of a 0.025 M aqueous solution of boric acid ($K_a = 5.9 \times 10^{-10}$)?

$$B(OH)_3(aq) + H_2O(l) \rightleftharpoons B(OH)_4^-(aq) + H_3O^+(aq)$$

$$K_a = \frac{[B(OH)_4^-][H_3O^+]}{[B(OH)_3]} = 5.9 \times 10^{-10}$$

$$\frac{[H_3O^+]}{[B(OH)_3]} = \frac{x}{0.025} = 5.9 \times 10^{-10}$$

$$x = 3.8 \times 10^{-6}$$

$$[H_3O^+] = 3.8 \times 10^{-6}$$

$$\Rightarrow \rho pH = 5.4$$

3. (10 pts) Ephedrine ($C_{10}H_{15}ON$) is a base that is used in nasal sprays as a decongestant.
   a) Write an equation for its equilibrium reaction with water.

$$C_{10}H_{15}ON + H_2O \rightleftharpoons C_{10}H_{15}ONH^+ + OH^- \quad \text{(similar to NH}_3\text{)}$$

b) The $K_b$ for ephedrine is $1.4 \times 10^{-4}$. Calculate $K_a$ for its conjugate acid.

$$C_{10}H_{15}ONH^+ + H_2O \rightleftharpoons H_3O^+ + C_{10}H_{15}ON$$

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

$$K_a = 7.14 \times 10^{-11}$$

$$pK_a(Ep) = 3.85 : \text{ ephedrine is a stronger base than ammonia (pK}_a = 4.74\text{)}$$

4. (10 pts) Phthalic acid ($H_2C_8H_4O_4$), abbreviated $H_2$Ph, is a diprotic acid. Its acid dissociation constants are $K_{a1} = 1.26 \times 10^{-3}$ and $K_{a2} = 3.10 \times 10^{-6}$. If 0.0100 mol of phthalic acid is dissolved and diluted to 1.000 liter of solution, calculate the equilibrium concentrations of all species present. Be careful of approximations, state each clearly and check each. Here’s the quadratic eq, if you need it.

$$H_2C_8H_4O_4 + H_2O \rightleftharpoons H_3C_8H_4O_4^+ + OH^-$$

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

$$K_{a1} = \frac{[H_3C_8H_4O_4^+][OH^-]}{[H_2C_8H_4O_4]} \Rightarrow x = 0.00355$$

$$K_{a2} = \frac{[H_2O][H_3C_8H_4O_4^+]}{[H_3C_8H_4O_4]} \Rightarrow x = 0.00003$$

$$x = \text{check: 0.00355 - 0.00003 = 0.00352 \ OK}$$

$$\therefore \text{above all are still OK}$$

$$\text{AND } [OH^-] = 3.10 \times 10^{-6}$$