Ch. 16 Additional Problem

0.0250 M H_3PO_4

$K_{a1} = 7.5 \times 10^{-3}$
$K_{a2} = 6.2 \times 10^{-8}$
$K_{a3} = 4.2 \times 10^{-13}$

① $H_3PO_4 + H_2O \rightleftharpoons H_3O^+ + H_2PO_4^-$

	H_3PO_4	H_2O	H_3O^+	$H_2PO_4^-$
i	0.0250 M	lots	0	0
Δ	$-x$		$+x$	$+x$
eq.	$0.0250 - x$		x	x

$$K_{a1} = \frac{x^2}{0.0250 - x} = 7.5 \times 10^{-3}$$

$\frac{[HA]}{K_a} = \frac{0.0250}{7.5 \times 10^{-3}} = 3.33$

not ok to neglect x

Use successive approximations,

① neglect x $\quad \frac{x^2}{0.0250} = 7.5 \times 10^{-3} \qquad x^2 = (0.0250)(7.5 \times 10^{-3})$

$x_1 = \sqrt{(7.5 \times 10^{-3})(0.0250}} = 0.01369$ M

$x_2 = \sqrt{K_a(0.0250 - x_1)} = 9.2 \times 10^{-3}$ M

$x_3 = \sqrt{K_a(0.0250 - x_2)} = 1.088 \times 10^{-2}$ M

$x_4 = \quad = 1.0289 \times 10^{-2}$ M

$x_5 = \quad = 1.05 \times 10^{-2}$

$x_6 \quad 1.042 \times 10^{-2}$ close enough! (could have stopped sooner....)

② $H_2PO_4^- + H_2O \rightleftharpoons H_3O^+ + HPO_4^{2-}$

	$H_2PO_4^-$	H_2O	H_3O^+	HPO_4^{2-}
i	1.042×10^{-2}	lots	1.042×10^{-2} M	0
Δ	$-y$		$+y$	$+y$
eq.	$1.042 \times 10^{-2} - y$		1.042×10^{-2} M $+ y$	y

$$K_{a2} = \frac{(1.042 \times 10^{-2} + y)(y)}{(1.042 \times 10^{-2} - y)} = 6.2 \times 10^{-8}$$

← very small neglect y's

$$K_{a2} = \frac{(1.042\times10^{-2})(y)}{(1.042\times10^{-2})} \qquad y = K_{a2} = 6.2\times10^{-8}$$

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	HPO_4^{2-}	+ H_2O	⇌ H_3O^+	+ PO_4^{3-}
i	6.2×10^{-8} M	lots	1.042×10^{-2} M	∅
Δ	$-z$		$+z$	$+z$
eq.	$6.2\times10^{-8} - z$		$1.042\times10^{-2} + z$	z

$$K_{a3} = \frac{(1.042\times10^{-2} + z)(z)}{(6.2\times10^{-8} - z)} = 4.2\times10^{-13}$$

K_{a3} very small. z is very small. ok to neglect.

$$K_{a3} = \frac{(1.042\times10^{-2})(z)}{6.2\times10^{-8}} = 4.2\times10^{-13}$$

$$\text{so } z = \frac{(4.2\times10^{-13})(6.2\times10^{-8})}{(1.042\times10^{-2})} = 2.497\times10^{-18}$$

$[H_3PO_4] = 0.0250 - 0.01042 = 0.01458 = 0.015\text{ M } H_3PO_4$

$[H_2PO_4^-] = x = 0.010\text{ M}$

$[HPO_4^{2-}] = y = 6.2\times10^{-8}\text{ M}$

$[PO_4^{3-}] = z = 2.5\times10^{-18}\text{ M}$

$[H_3O^+] = 0.010\text{ M}$

$[OH^-] = \frac{K_w}{[H_3O^+]} = \frac{1.0\times10^{-14}}{0.01042} = 9.6\times10^{-13}\text{ M } OH^-$

$pH = -\log[H_3O^+] = -\log(0.01042) = 1.98$