Diprotic and Polyprotic Acids

Important Points

- **When an acid has more than one ionizable proton, the protons are lost in successive reactions.**

Phosphoric Acid

$$H_3PO_4(aq) \rightleftharpoons H^+(aq) + H_2PO_4^-(aq)$$

$$H_2PO_4^-(aq) \rightleftharpoons H^+(aq) + HPO_4^{2-}(aq)$$

$$HPO_4^{2-}(aq) \rightleftharpoons H^+(aq) + PO_4^{3-}(aq)$$

Important Points

- **When an acid has more than one ionizable proton, the protons are lost in successive reactions.**
- **Each ionization is characterized by a separate K_a value.**
- **Each successive K_a is smaller than the preceding one.**

Phosphoric Acid

7.5×10^{-3}

$$H_3PO_4(aq) \rightleftharpoons H^+(aq) + H_2PO_4^-(aq)$$

6.2×10^{-8}

$$H_2PO_4^-(aq) \rightleftharpoons H^+(aq) + HPO_4^{2-}(aq)$$

4.8×10^{-13}

$$HPO_4^{2-}(aq) \rightleftharpoons H^+(aq) + PO_4^{3-}(aq)$$

Important Points

- **When an acid has more than one ionizable proton, the protons are lost in successive reactions.**
- **Each ionization is characterized by a separate K_a value.**
- **Each successive K_a is smaller than the preceding one.**
- **For a weak polyprotic acid, the first ionization produces much of the H^+ ions.**

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Sulfuric Acid

H_2SO_4 is a strong acid in its first ionization; but a weak acid in its second.

$$K_a = \text{very large}$$

$$HO - SO_2 - OH \rightleftharpoons HO - SO_2 - O^- + H^+$$

$$K_a = 0.013$$

$$HO - SO_2 - O^- \rightleftharpoons {}^-O - SO_2 - O^- + H^+$$

Calculate the pH of a 0.056 M solution of H_2SO_4.

$$H_2SO_4 \rightleftharpoons HSO_4^- + H^+$$

Init:	**0.056 *M***	**0**	**0**

After first ionization:

0	**0.056 *M***	**0.056 *M***

$$HSO_4^- \rightleftharpoons SO_4^{2-} + H^+$$

0.056 *M*	**0**	**0.056 *M***
0.056 *M* - x	**x**	**0.056 *M* + x**

$$HSO_4^- \rightleftharpoons SO_4^{2-} + H^+$$

HSO_4^-	SO_4^{2-}	H^+
$.056 - x$	x	$.056 + x$

$$K_a = \frac{[SO_4^{2-}]\,[H^+]}{[HSO_4^-]}$$

$$.013 = \frac{(x)(.056 + x)}{(.056 - x)}$$

assume x is small compared 0.056

$$0.013 = \frac{(x)(.056)}{(.056)}$$

$$x = .013$$

$$100 \times \frac{.013}{(.056)}$$

$$= 23\%$$

$$HSO_2^- \rightleftharpoons SO_4^{2-} + H^+$$

HSO_2^-	SO_4^{2-}	H^+
.056 - x	x	.056 + x

$$K_a = \frac{[SO_4^{2-}]\,[H^+]}{[HSO_4^-]}$$

$$.013 = \frac{(x)(.056 + x)}{(.056 - x)}$$

$x = .056$;

so the assumption is invalid

$$HSO_4^- \rightleftharpoons SO_4^{2-} + H^+$$

HSO_4^-	SO_4^{2-}	H^+
$.056 - x$	x	$.056 + x$

$$K_a = \frac{[SO_4^{2-}]\,[H^+]}{[HSO_4^-]}$$

$$.013 = \frac{(x)(.056 + x)}{(.056 - x)}$$

$$x^2 + .069\,x - 7.28 \times 10^{-4} = 0$$

$$x = \frac{-.069 \pm \sqrt{.069^2 - 4(1)(-7.28 \times 10^{-4})}}{2(1)}$$

$$x = 0.0093$$

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HSO_4^-	SO_4^{2-}	H^+
.056 - x	x	.056 + x

$$K_a = \frac{[SO_4^{2-}]\,[H^+]}{[HSO_4^-]}$$

$$.013 = \frac{(x)(.056 + x)}{(.056 - x)}$$

$$x = 0.0093$$

$$[H^+] = (.056 + x)$$

$$= 0.063\ M$$

pH = 1.19

Quadratic equation

$$ax^2 + bx + c = 0$$

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

$$x^2 + .069\,x - 7.28 \times 10^{-4} = 0$$

$$x = \frac{-.069 \pm \sqrt{069^{\,2} - 4(1)(-7.28 \times 10^{-4})}}{2(1)}$$

$$x = 0.0093$$