

Homework 3

18. When a strong acid (HX) is added to water, the reaction $\text{HX} + \text{H}_2\text{O} \rightarrow \text{H}_3\text{O}^+ + \text{X}^-$ basically goes to completion. All strong acids in water are completely converted into H_3O^+ and X^- . Thus, no acid stronger than H_3O^+ will remain undissociated in water. Similarly, when a strong base (B) is added to water the reaction $\text{B} + \text{H}_2\text{O} \rightarrow \text{BH}^+ + \text{OH}^-$ basically goes to completion. All bases stronger than OH^- are completely converted into OH^- and BH^+ . Even though there are acids and bases stronger than H_3O^+ and OH^- , in water these acids and bases are completely converted into H_3O^+ and OH^- .

22. a. The weaker the X-H bond, the stronger the acid.
 b. As the electronegativity of neighboring atoms increases, the strength of the acid increases.
 c. As the number of oxygen atoms increases, the strength of the acid increases.

32.

	Acid	Base	Conjugate Base of Acid	Conjugate Acid of Base
a.	$\text{Al}(\text{H}_2\text{O})_6^{3+}$	H_2O	$\text{Al}(\text{H}_2\text{O})_5(\text{OH})^{2+}$	H_3O^+
b.	HONH_3^+	H_2O	HONH_2	H_3O^+
c.	HOCl	$\text{C}_6\text{H}_5\text{NH}_2$	OCl^-	$\text{C}_6\text{H}_5\text{NH}_3^+$

38. a. H_2O ; The conjugate bases of strong acids are terrible bases ($K_b < 10^{-14}$)
 b. NO_2^- ; The conjugate bases of weak acids are weak bases ($10^{-14} < K_b < 1$)
 c. OC_6H_5^- ; For a conjugate acid-base pair, $K_a \cdot K_b = K_w$. From this relationship, the stronger the acid the weaker the conjugate base (K_b decrease as K_a increases). Since HCN is a stronger acid than HOC_6H_5 (K_a for HCN $>$ K_a for HOC_6H_5), OC_6H_5^- will be a stronger base than CN^- .

42. a. $\text{H}_2\text{O}(\text{l}) \leftrightarrow \text{H}^+(\text{aq}) + \text{OH}^-(\text{aq})$ $K_w = 2.92 \cdot 10^{-14} = [\text{H}^+][\text{OH}^-]$
 In pure water $[\text{H}^+] = [\text{OH}^-]$, so $2.92 \cdot 10^{-14} = [\text{H}^+]^2$, $[\text{H}^+] = 1.71 \cdot 10^{-7} \text{ M} = [\text{OH}^-]$
 b. $\text{pH} = -\log[\text{H}^+] = -\log(1.71 \cdot 10^{-7}) = 6.767$
 c. $[\text{H}^+] = K_w/[\text{OH}^-] = 2.92 \cdot 10^{-14}/0.10 = 2.9 \cdot 10^{-13} \text{ M}$; $\text{pH} = -\log(2.9 \cdot 10^{-13}) = 12.54$

50. $90.0 \cdot 10^{-3} \text{ L} \times 5.00 \text{ mol/L} = 0.450 \text{ mol H}^+$ from HCl
 $30.0 \cdot 10^{-3} \text{ L} \times 8.00 \text{ mol/L} = 0.240 \text{ mol H}^+$ from HCO_3^-
 $[\text{H}^+] = (0.450 \text{ mol} + 0.240 \text{ mol})/1.00 \text{ L} = 0.690 \text{ M}$, $\text{pH} = -\log(0.690) = 0.161$
 $\text{pOH} = 14 - 0.161 = 13.839$; $[\text{OH}^-] = 10^{-13.839} = 1.45 \cdot 10^{-14} \text{ M}$

66.	HF	\leftrightarrow	H ⁺	+	F ⁻
Initial	0.100 M		~0		0
	x mol/L of HF dissociates to reach equilibrium				
Change	-x	\rightarrow	x		+x
Equil.	(0.100 - x) M		x		x

$$K_a = \frac{[\text{H}^+][\text{F}^-]}{[\text{HF}]} = \frac{x^2}{(0.100 - x)}; x = [\text{H}^+] = [\text{F}^-] = 0.081 \times (0.100 \text{ M}) = 8.1 \cdot 10^{-3} \text{ M}$$

$$[\text{HF}] = 0.100 - 8.1 \cdot 10^{-3} = 0.092 \text{ M}; K_a = \frac{(8.1 \cdot 10^{-3})^2}{0.092} = 7.1 \cdot 10^{-4}$$

84. Major species: H₂NNH₂ (K_b = 3.0 • 10⁻⁶) and H₂O (K_b = K_w = 1.0 • 10⁻¹⁴); The weak base H₂NNH₂ will dominate OH⁻ production. We must perform a weak base equilibrium calculation.

	H ₂ NNH ₂	+	H ₂ O	\leftrightarrow	H ₂ NNH ₃ ⁺	+	OH ⁻
Initial	2.0 M				0 M		0
	x mol/L of H ₂ NNH ₂ reacts with H ₂ O to reach equilibrium						
Change	-x				+x		+x
Equil.	(2.0 - x) M				x		x

$$K_b = 3.0 \cdot 10^{-3} \text{ M}, = \frac{[\text{H}_2\text{NNH}_3^+][\text{OH}^-]}{[\text{H}_2\text{NNH}_2]} = \frac{x^2}{(2.0 - x)} \approx \frac{x^2}{2.0}$$

$$x = [\text{OH}^-] = 2.4 \cdot 10^{-3} \text{ M}; \text{pOH} = 2.62; \text{pH} = 11.38 \text{ Assumption good (x is 0.12\% of 2.0)}$$

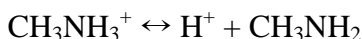
$$[\text{H}_2\text{NNH}_3^+] = 2.4 \cdot 10^{-3} \text{ M}; [\text{H}_2\text{NNH}_2] = 2.0 \text{ M}; [\text{H}^+] = 10^{-11.38} = 4.2 \cdot 10^{-12} \text{ M}$$

112. a. KCl \rightarrow K⁺ + Cl⁻ neutral, K⁺ and Cl⁻ have no effect on pH.

- b. NH₄C₂H₃O₂ \rightarrow NH₄⁺ + C₂H₃O₂⁻ neutral, NH₄⁺ is a weak acid and C₂H₃O₂⁻ is a weak base.

$$\text{Since } K_a(\text{NH}_4^+) = K_b(\text{C}_2\text{H}_3\text{O}_2^-), \text{pH} = 7.00$$

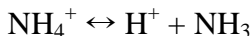
- c. CH₃NH₃Cl \rightarrow CH₃NH₃⁺ + Cl⁻ acidic, CH₃NH₃⁺ is a weak acid and Cl⁻ has no effect on the pH.



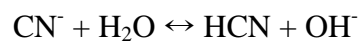
- d. KF \rightarrow K⁺ + F⁻ basic, F⁻ is a weak base and K⁺ has no effect on the pH.



- e. NH₄F \leftrightarrow NH₄⁺ + F⁻ acidic; NH₄⁺ is a weak acid and F⁻ is a weak base. Since K_a(NH₄⁺) > K_b(F⁻), then the solution is acidic.



f. $\text{CH}_3\text{NH}_3\text{CN} \leftrightarrow \text{CH}_3\text{NH}_3^+ + \text{CN}^-$ basic; CH_3NH_3^+ is a weak acid and CN^- is a weak base. Since $K_b(\text{CN}^-) > K_a(\text{CH}_3\text{NH}_3^+)$, the solution is basic.



122. $\text{Zn}(\text{OH})_2(\text{s}) + 2\text{H}^+(\text{aq}) \rightarrow \text{Zn}^{2+}(\text{aq}) + 2\text{H}_2\text{O}(\text{l})$ (Bronstead-Lowry base)
 $\text{Zn}(\text{OH})_2(\text{s}) + 2\text{OH}^-(\text{aq}) \rightarrow \text{Zn}(\text{OH})_4^{2-}(\text{aq})$ (Lewis acid)