16 • Acids, Bases and salts

16.9 Salts Lab

We have seen that a conjugate acid or a conjugate base can react with water to produce either hydronium ion or hydroxide ion. This behavior is called **hydrolysis**. The conjugate acids and bases that we have encountered are ions. As such, they can be added to a solution in the form of a salt. For example, acetate ion is the conjugate base of acetic acid. We can add acetate ion to a solution by adding sodium acetate.

$$NaC_2H_3O_2(s) \xrightarrow{H_2O} Na^+(aq) + C_2H_3O_2^-(aq)$$

Recall that soluble ionic salts are strong electrolytes. Because of acetate's tendency to hydrolyze water, a solution of sodium acetate is basic.

$$C_2H_3O_2^-(aq) + H_2O(l) \rightleftharpoons HC_2H_3O_2(aq) + OH^-(aq)$$

The acetate ion contributes (by hydrolysis of water) to the OH^- concentration. The sodium ion does not react with water. It is the conjugate acid of a *strong* base, sodium hydroxide, and is therefore a *weak* conjugate acid. Remember: *weak conjugates* do *not* react with water.

$$Na^+(aq) + H_2O(l) \rightarrow \text{no reaction}$$

The acidity or basicity of a salt depends on the salt's constituent ion. We can think of all salts as the products of acid-base neutralization reactions. For example, hydrochloric acid and sodium hydroxide react to form water and sodium chloride. HCl is a strong acid; therefore its conjugate, chloride ion, is weak. Sodium hydroxide is a strong base; therefore its conjugate, sodium ion, is weak. When both of the ions of the salt are *weak* conjugates, the solution is neutral. A solution of sodium chloride has a pH of 7.

The pH of a salt solution can be predicted qualitatively by considering the ionic constituents of the salt.

1. *Salts derived from a strong base and a strong acid:* The solution has a pH of 7.
2. *Salts derived from a strong base and a weak acid:* The solution has a pH above 7.
3. *Salts derived from a weak base and strong acid:* The solution has a pH below 7.
4. *Salts derived from a weak base and a weak acid:* The solution has a pH greater than 7.

pH of Salts Lab

Materials:

- (10) large test tubes
- (2) test tube racks
- Wash bottle
- Glass stir rods
- pH paper
- Digital pH Probe
- The salts listed in the table

Salt	Source of Conjugate Cation (weak or strong)	Source of Conjugate Anion (weak or strong)	Which one determine pH?	Predicted pH Range (acidic or basic)	pH (pH paper)	pH (probe)
NaCl						
NH_4Cl						
$Al(NO_3)_3$						
KBr						
Na_2CO_3						
$(NH_4)_2CO_3$						
NaClO						
$Ca(NO_3)_2$						
$NH_4C_2H_3O_2$						
$Na_2C_2O_4$						
$CuCl_2$						
$NaC_2H_3O_2$						

Postlab Questions:

1. There were (2) salts in this lab that were derived from weak acids and bases. Write the salts below and look-up the K_a and K_b values for the acids and bases of these conjugates. Determine if the salt is acidic or basic by comparing the equilibrium values. Show how the stronger conjugate hydrolyzes in water to determine the pH.

a) Salt Formula _____ Predicted pH [Acidic / Basic / Neutral] (circle one)

anion: _____ K_b value _____

cation: _____ K_a value _____

Hydrolysis equation _____

a) Salt Formula _____ Predicted pH [Acidic / Basic / Neutral] (circle one)

anion: _____ K_b value _____

cation: _____ K_a value _____

Hydrolysis equation _____

Helpful Tables

TABLE 4.2 Common Strong Acids and Bases

Strong Acids	Strong Bases
Hydrochloric, HCl	Group 1A metal hydroxides (LiOH, NaOH, KOH, RbOH, CsOH)
Hydrobromic, HBr	Heavy group 2A metal hydroxides [$Ca(OH)_2$, $Sr(OH)_2$, $Ba(OH)_2$]
Hydroiodic, HI	
Chloric, $HClO_3$	
Perchloric, $HClO_4$	
Nitric, HNO_3	
Sulfuric, H_2SO_4	

Table 17.3 • **Ionization Constants for Some Acids and Their Conjugate Bases**

Acid Name	Acid	K_a	Base	K_b	Base Name
Perchloric acid	$HClO_4$	large	ClO_4^-	very small	perchlorate ion
Sulfuric acid	H_2SO_4	large	HSO_4^-	very small	hydrogen sulfate ion
Hydrochloric acid	HCl	large	Cl^-	very small	chloride ion
Nitric acid	HNO_3	large	NO_3^-	very small	nitrate ion
Hydronium ion	H_3O^+	1.0	H_2O	1.0×10^{-14}	water
Sulfurous acid	H_2SO_3	1.2×10^{-2}	HSO_3^-	8.3×10^{-13}	hydrogen sulfite ion
Hydrogen sulfate ion	HSO_4^-	1.2×10^{-2}	SO_4^{2-}	8.3×10^{-13}	sulfate ion
Phosphoric acid	H_3PO_4	7.5×10^{-3}	$H_2PO_4^-$	1.3×10^{-12}	dihydrogen phosphate ion
Hexaaquairon(III) ion	$Fe(H_2O)_6^{3+}$	6.3×10^{-3}	$Fe(H_2O)_5OH^{2+}$	1.6×10^{-12}	pentaaquahydroxoiron(III) ion
Hydrofluoric acid	HF	7.2×10^{-4}	F^-	1.4×10^{-11}	fluoride ion
Nitrous acid	HNO_2	4.5×10^{-4}	NO_2^-	2.2×10^{-11}	nitrite ion
Formic acid	HCO_2H	1.8×10^{-4}	HCO_2^-	5.6×10^{-11}	formate ion
Benzoic acid	$C_6H_5CO_2H$	6.3×10^{-5}	$C_6H_5CO_2^-$	1.6×10^{-10}	benzoate ion
Acetic acid	CH_3CO_2H	1.8×10^{-5}	$CH_3CO_2^-$	5.6×10^{-10}	acetate ion
Propanoic acid	$CH_3CH_2CO_2H$	1.3×10^{-5}	$CH_3CH_2CO_2^-$	7.7×10^{-10}	propanoate ion
Hexaaquaaluminum ion	$Al(H_2O)_6^{3+}$	7.9×10^{-6}	$Al(H_2O)_5OH^{2+}$	1.3×10^{-9}	pentaaquahydroxoaluminum ion
Carbonic acid	H_2CO_3	4.2×10^{-7}	HCO_3^-	2.4×10^{-8}	hydrogen carbonate ion
Hexaaquacopper(II) ion	$Cu(H_2O)_6^{2+}$	1.6×10^{-7}	$Cu(H_2O)_5OH^+$	6.25×10^{-8}	pentaaquahydroxocopper(II) ion
Hydrogen sulfide	H_2S	1×10^{-7}	HS^-	1×10^{-7}	hydrogen sulfide ion
Dihydrogen phosphate ion	$H_2PO_4^-$	6.2×10^{-8}	HPO_4^{2-}	1.6×10^{-7}	hydrogen phosphate ion
Hydrogen sulfite ion	HSO_3^-	6.2×10^{-8}	SO_3^{2-}	1.6×10^{-7}	sulfite ion
Hypochlorous acid	HClO	3.5×10^{-8}	ClO^-	2.9×10^{-7}	hypochlorite ion
Hexaaqualead(II) ion	$Pb(H_2O)_6^{2+}$	1.5×10^{-8}	$Pb(H_2O)_5OH^+$	6.7×10^{-7}	pentaaquahydroxolead(II) ion
Hexaaquacobalt(II) ion	$Co(H_2O)_6^{2+}$	1.3×10^{-9}	$Co(H_2O)_5OH^+$	7.7×10^{-6}	pentaaquahydroxocobalt(II) ion
Boric acid	$B(OH)_3(H_2O)$	7.3×10^{-10}	$B(OH)_4^-$	1.4×10^{-5}	tetrahydroxoborate ion
Ammonium ion	NH_4^+	5.6×10^{-10}	NH_3	1.8×10^{-5}	ammonia
Hydrocyanic acid	HCN	4.0×10^{-10}	CN^-	2.5×10^{-5}	cyanide ion
Hexaaquairon(II) ion	$Fe(H_2O)_6^{2+}$	3.2×10^{-10}	$Fe(H_2O)_5OH^+$	3.1×10^{-5}	pentaaquahydroxoiron(II) ion
Hydrogen carbonate ion	HCO_3^-	4.8×10^{-11}	CO_3^{2-}	2.1×10^{-4}	carbonate ion
Hexaaquanickel(II) ion	$Ni(H_2O)_6^{2+}$	2.5×10^{-11}	$Ni(H_2O)_5OH^+$	4.0×10^{-4}	pentaaquahydroxonickel(II) ion
Hydrogen phosphate ion	HPO_4^{2-}	3.6×10^{-13}	PO_4^{3-}	2.8×10^{-2}	phosphate ion
Water	H_2O	1.0×10^{-14}	OH^-	1.0	hydroxide ion
Hydrogen sulfide ion*	HS^-	1×10^{-19}	S^{2-}	1×10^{5}	sulfide ion
Ethanol	C_2H_5OH	very small	$C_2H_5O^-$	large	ethoxide ion
Ammonia	NH_3	very small	NH_2^-	large	amide ion
Hydrogen	H_2	very small	H^-	large	hydride ion

Increasing Acid Strength ↑ ↓ Increasing Base Strength

*The values of K_a for HS^- and K_b for S^{2-} are estimates.