Answers to Review #7: Acids, Bases and Salts

1. Know the meanings of and be able to apply the following terms:

Bronsted-Lowry acid	strong acid	concentrated	chemical indicator
Bronsted-Lowry base	strong base	dilute	titration
conjugate acid/base pair	weak acid	equivalence point	buffer
amphiprotic (amphoteric)	weak base	endpoint	salt

2. Consider these acids: $HClO_2$, HCN, HF, HCl

a) Arrange these acids from weakest to strongest:

HCN (Ka = 6.2×10^{-10}) < HF (Ka = 6.3×10^{-4}) < $HClO_2$ (Ka = 1.1×10^{-2}) < HCl (a strong acid)

b) Arrange these acids from lowest to highest pH:

HCl (a strong acid) < $HClO_2$ < HF < HCN (the weakest acid)

c) Arrange these acids from poorest to best electrolytes:

HCN (the weakest acid is the poorest electrolyte) < HF < $HClO_2$ < HCl (a strong acid)

d) Which of these acids will ionize the most in water? **HCl**

- all acids, because they are covalent compounds, will ionize in water
- because it is a strong acid, HCl will completely ionize
- the other acids are weak, so they will only partially ionize in water

e) Which one of these acids will produce the solution with the highest concentration of H_3O^+ (aq)? **HCl**

- because it is a strong acid, HCl will completely ionize in water so it will form the highest $[H_3O^+]$

f) Which acid will react most slowly with zinc metal? **HCN**

- the weakest acid, HCN will form the lowest concentration of H_3O^+ (aq) so it will react the most slowly with Zn metal

g) Write the chemical formula for the conjugate base of each acid:

- $HClO_2$ has the conjugate base ClO_2^{1-}
- HCN has the conjugate base CN^{1-}
- HF has the conjugate base F^{1-}
- HCl has the conjugate base Cl^{1-}

h) Arrange the conjugate bases from weakest to strongest:

- the strongest acid has the weakest conjugate base (remember Ka x Kb = Kw, so as the Ka of the acid increases, the Kb for its conjugate base must decrease to keep Kw is constant)
- Cl^{1-} (the weakest conjugate base) < ClO_2^{1-} < F^{1-} < CN^{1-} (the strongest conjugate base)

3. Calculate the pH of 0.10 M solutions of HCl and $HClO_2$. (pH of HCl is 1.00, pH of $HClO_2$ is 1.55)

4. Write the chemical formula for the conjugate acids of these basic species:
   - conjugate acids have one more H+ ion, so simply add an H+ to each species

   NH_3: **NH_4^+** OCl^-: **HOCl** HSO_4^- : **H_2SO_4** H_2O: **H_3O^+** OH^- : **H_2O** HBO_3^{2-} : **$H_2BO_3^{1-}$**

5. Write chemical formulas showing the following species ionizing (hydrolyzing) in water. Identify all Bronsted-Lowry acids and Bronsted-Lowry bases for each reversible reaction.

a) N_2H_4 (l) + H_2O (l) ↔ $N_2H_5^{1+}$ (aq) + OH^{1-} (aq)
base acid acid base

b) $HCOOH$ + H_2O (l) ↔ H_3O^{1+} (aq) + $HCOO^{1-}$ (aq)
acid base acid base

c) OCN^- (aq) + H_2O (l) ↔ HOCN (aq) + OH^{1-} (aq)
base acid acid base

d) HSO_4^- (aq) (as a base) + H_2O (l) ↔ H_2SO_4 (aq) + OH^{1-} (aq)
base acid acid base

e) HSO_4^- (aq) (as an acid) + H_2O (l) ↔ SO_4^{-2} (aq) + H_3O^{1+} (aq)
acid base base acid

f) PO_4^{3-} (aq) + H_2O (l) ↔ HPO_4^{-2} (aq) + OH^{1-} (aq)
base acid acid base

g) NH_4^+ (aq) + H_2O (l) ↔ NH_3 (aq) + H_3O^{1+} (aq)
acid base base acid

6. Write the neutralization reaction that occurs when the following acids and bases are mixed. Identify the salt. Based on the salt, describe the pH of the final solution. (Salts are in **BOLD**)

a) HCN (aq) + NaOH (aq) → H_2O (l) + **NaCN (aq)** pH of salt: **basic**

b) $HClO_3$ (aq) + NH_4OH (aq) → H_2O (l) + **NH_4ClO_3 (aq)** pH of salt: **acidic**

c) 2 HF (aq) + $Ca(OH)_2$ (aq) → 2 H_2O (l) + **CaF_2 (aq)** pH of salt: **basic**

d) $Co(OH)_3$ (aq) + 3 HI (aq) → 3 H_2O (l) + **CoI_3 (aq)** pH of salt: **acidic**

e) CH_3COOH (aq) + KOH (aq) → H_2O (l) + **KCH_3COO (aq)** pH of salt: **basic**

f) $Ba(OH)_2$ (aq) + 2 HNO_3 (aq) → 2 H_2O (l) + **$Ba(NO_3)_2$ (aq)** pH of salt: **neutral**

g) H_2SO_4 (aq) + $Be(OH)_2$ (aq) → 2 H_2O (l) + **$BeSO_4$ (aq)** pH of salt: **acidic**

7. Calculate the value of Kb for the following conjugate bases:

a) HCO_3^{1-} (HCO_3^{1-} is the conjugate base of H_2CO_3, so Kw) Ka of H_2CO_3) Kb = 2.2×10^{-8}

b) CO_3^{2-} (CO_3^{2-} is the conjugate base of HCO_3^{1-}, so Kw) Ka of HCO_3^{1-}) Kb = 2.1×10^{-4}

c) SO_4^{2-} (SO_4^{2-} is the conjugate base of HSO_4^{1-}, so Kw) Ka of HSO_4^{1-}) Kb = 1.0×10^{-12}

d) $H_2PO_4^{1-}$ ($H_2PO_4^{1-}$ is the conjugate base of H_3PO_4, so Kw) Ka of H_3PO_4) Kb = 1.4×10^{-12}

e) PO_4^{3-} (PO_4^{3-} is the conjugate base of HPO_4^{2-}, so Kw) Ka of HPO_4^{2-}) Kb = 2.1×10^{-2}

8. Calculate the $[H_3O^+]$ concentration of the final solution, if:

a) 28.0 mL of 15.0 M HNO_3 is diluted to 1.0 L (0.42 M)

b) a solution of HF has a pH of 2.56 (2.8×10^{-3} M)

c) the pOH of a solution is 5.15 (1.4×10^{-9} M)

d) 3.50 g of KOH is dissolved in 500.0 mL of distilled water (8.02×10^{-14} M)

9. How much 12.0 M HCl must be diluted to make 1.50 L of 1.00 M HCl solution? (0.125 L)

10. Calculate the pH of a 1.25 M solution of acetic acid. (2.32)

11. If the pH of a 2.00 M solution of cyanic acid (HOCN) is 1.58, calculate the K_a for this acid. (3.5×10^{-4})

12. A 0.0125 M solution of hypobromous acid has a pH of 5.23 at 25°C. Calculate the K_a for this acid. (2.8×10^{-9})

13. 6.83 mL of a solution of NaOH is standardized against 3.06 g of potassium hydrogen phthlate ($KHC_8O_4H_4$). Calculate the concentration of the base. (2.19 M)

14. What volume of 0.765 M H_3PO_4 is required to exactly neutralize 2.000 g of calcium hydroxide? (0.0235 L of H_3PO_4)

15. What is the concentration of a solution of hydroiodic acid if it takes 13.16 mL of 0.508 M KOH solution to exactly titrate 25.00 mL of the hydroiodic acid? (0.267 M)

16. 9.88 mL of 1.244 M sodium hydroxide solution is required to exactly titrate 10.00 mL of sulfuric acid. Calculate the concentration of the sulfuric acid solution. (0.615 M)