KEY

Study Guide: Acids and Bases

1) List at least three characteristic properties of acids and three of bases.

- **ACIDS**
  - pH less than 7
  - Have a sour taste
  - Change the color of many indicators
  - Are corrosive (react with metals)
  - Neutralize bases
  - Conduct an electric current

- **BASES**
  - pH greater than 7
  - Have a bitter taste
  - Change the color of many indicators
  - Have a slippery feeling
  - Neutralize acids
  - Conduct an electric current

2) Identify the acid, base, conjugate acid, and conjugate base in the following reactions:

   a) $\text{HNO}_3 + \text{H}_2\text{O} \leftrightarrow \text{H}_3\text{O}^+ + \text{NO}_3^-$
      - **ACID**: HNO$_3$
      - **BASE**: H$_2$O
      - **C. ACID**: H$_3$O$^+$
      - **C. BASE**: NO$_3^-$

   b) $\text{H}_2\text{C}_2\text{O}_4 + \text{CH}_3\text{NH}_2 \leftrightarrow \text{HC}_2\text{O}_4^- + \text{CH}_3\text{NH}_3^+$
      - **ACID**: H$_2$C$_2$O$_4$
      - **BASE**: CH$_3$NH$_2$
      - **C. BASE**: CH$_3$NH$_3^+$
      - **C. ACID**: HC$_2$O$_4^-$

   c) $\text{NH}_4^+ + \text{H}_2\text{O} \leftrightarrow \text{NH}_3 + \text{H}_3\text{O}^+$
      - **ACID**: NH$_4^+$
      - **BASE**: H$_2$O
      - **C. BASE**: NH$_3$
      - **C. ACID**: H$_3$O$^+$

3) Complete and balance the following neutralization / acid-base reactions:

   a) $2\text{NaOH} + \text{H}_2\text{CO}_3 \rightarrow 2\text{H}_2\text{O} + \text{Na}_2\text{CO}_3$
   
   b) $\text{H}_2\text{SO}_4 + \text{Ba(OH)}_2 \rightarrow 2\text{H}_2\text{O} + \text{BaSO}_4$

   c) $\text{H}_2\text{S} + 2\text{KOH} \rightarrow 2\text{H}_2\text{O} + \text{K}_2\text{S}$

   d) $\text{Al(OH)}_3 + 3\text{HBr} \rightarrow 3\text{H}_2\text{O} + \text{AlBr}_3$
4) Write a balanced: (1) formula unit, (2) total ionic, and (3) net ionic equation for each of the following acid-base reactions:

   a) \( 2 \text{KOH} + \text{H}_2\text{SO}_4 \rightarrow \)
      1) \( 2 \text{KOH} + \text{H}_2\text{SO}_4 \rightarrow 2\text{H}_2\text{O} + \text{K}_2\text{SO}_4 \)
      2) \( 2\text{K}^+(\text{aq}) + 2\text{OH}^-(\text{aq}) + 2\text{H}^+(\text{aq}) + \text{SO}_4^{2-}(\text{aq}) \rightarrow 2\text{H}_2\text{O}(l) + 2\text{K}^-(\text{aq}) + \text{SO}_4^{2-}(\text{aq}) \)
      3) \( \text{H}^+(\text{aq}) + \text{OH}^-(\text{aq}) \rightarrow \text{H}_2\text{O}(l) \)

   b) \( \text{HNO}_3 + \text{Ba(OH)}_2 \rightarrow \)
      1) \( 2\text{HNO}_3 + \text{Ba(OH)}_2 \rightarrow 2\text{H}_2\text{O} + \text{Ba(NO}_3)_2 \)
      2) \( 2\text{H}^+(\text{aq}) + 2\text{NO}_3^-(\text{aq}) + \text{Ba}^{2+}(\text{aq}) + 2\text{OH}^-(\text{aq}) \rightarrow 2\text{H}_2\text{O}(l) + 2\text{Ba}^{2+}(\text{aq}) + 2\text{NO}_3^-(\text{aq}) \)
      3) \( \text{H}^+(\text{aq}) + \text{OH}^-(\text{aq}) \rightarrow \text{H}_2\text{O}(l) \)

   c) \( \text{H}_2\text{CO}_3 + \text{Al(OH)}_3 \rightarrow \)
      1) \( 3\text{H}_2\text{CO}_3 + 2\text{Al(OH)}_3 \rightarrow 6\text{H}_2\text{O} + \text{Al}_2(\text{CO}_3)_3 \)
      2) \( 6\text{H}^+(\text{aq}) + 3\text{CO}_3^{2-}(\text{aq}) + 2\text{Al}^{3+}(\text{aq}) + 6\text{OH}^-(\text{aq}) \rightarrow 6\text{H}_2\text{O}(l) + 2\text{Al}^{3+}(\text{aq}) + 3\text{CO}_3^{2-}(\text{aq}) \)
      3) \( \text{H}^+(\text{aq}) + \text{OH}^-(\text{aq}) \rightarrow \text{H}_2\text{O}(l) \)

   d) \( \text{Ca(OH)}_2 + \text{HCl} \rightarrow \)
      1) \( \text{Ca(OH)}_2 + 2\text{HCl} \rightarrow 2\text{H}_2\text{O} + \text{CaCl}_2 \)
      2) \( \text{Ca}^{2+}(\text{aq}) + 2\text{OH}^-(\text{aq}) + 2\text{H}^+(\text{aq}) + 2\text{Cl}^-(\text{aq}) \rightarrow 2\text{H}_2\text{O}(l) + \text{Ca}^{2+}(\text{aq}) + 2\text{Cl}^-(\text{aq}) \)
      3) \( \text{H}^+(\text{aq}) + \text{OH}^-(\text{aq}) \rightarrow \text{H}_2\text{O}(l) \)

5) Given a salt, predict an acid-base pair which would produce the salt:

   a) \( \text{Al}_2(\text{SO}_4)_3 \)
      \( \text{Al(OH)}_3 + \text{H}_2\text{SO}_4 \)
   b) \( \text{NH}_4\text{F} \)
      \( \text{NH}_4\text{OH} + \text{HF} \)
   c) \( \text{CaCl}_2 \)
      \( \text{Ca(OH)}_2 + \text{HCl} \)
   d) \( \text{KBr} \)
      \( \text{KOH} + \text{HBr} \)

6) Solve the following acid-base titration problems:

   a) What is the molarity of sodium hydroxide, \( \text{NaOH} \), if 59.0 mL of the solution is titrated to the endpoint with 24.0 mL of 0.75 M sulfuric acid (\( \text{H}_2\text{SO}_4 \))? (Hint: write the balanced equation first!)\[ N_a V_a = N_b V_b \]
      \[ (1.5 \text{ N})(24.0 \text{ mL}) = (N_b)(59.0 \text{ mL}) \]
      \[ N_b = 0.61 \text{ N} = 0.61 \text{ M} \text{ NaOH} \]... or use alternative stoichiometry method

   b) A 55.6 mL sample of HCl is titrated with 79.9 mL of a 1.25 M solution of NaOH. What is the molarity of the HCl?\[ N_a V_a = N_b V_b \]
      \[ (N_b)(55.6 \text{ mL}) = (1.25 \text{ N})(79.9 \text{ mL}) \]
      \[ N_b = 1.79 \text{ N} = 1.79 \text{ M} \text{ HCl} \]... or use alternative stoichiometry method
7) If you have a 1.0 M solution of NaOH and a solution of HCl with an unknown concentration, explain how you would use titration to determine the concentration of the HCl solution. (Explain the steps)
   1) measure out a specific volume of acid of unknown concentration
   2) add 3-4 drops of indicator, such as phenolphthalein
   3) slowly titrate to endpoint with 1.0 M NaOH
   4) record volumes of acid and base needed for neutralization
   5) calculate the concentration of the acid

8) Perform the following molarity/normality problems:
   a) What is the normality of a 5.0 M phosphoric acid (H₃PO₄) solution? 15 N
   b) Find the normality of 5.6 g HBr in 450.0 mL of solution. 0.15 N
   c) If 45.0 mL of 0.30 N H₂SO₄ are neutralized by 75.0 mL of NaOH, find the normality of the NaOH. 0.18 N
   d) A 43.7 mL sample of Ba(OH)₂ is neutralized by 33.5 mL of 0.86 M HCl. What is the normality and molarity of the Ba(OH)₂ solution? 0.66 N = 0.33M

9) Calculate the pH and pOH of the following solutions:
   a) [H⁺] = 1 x 10⁻⁶ M  
      pH = 6  
      pOH = 8
   b) [OH⁻] = 1 x 10⁻⁹ M 
      pH = 5  
      pOH = 9
   c) [H⁺] = 7.4 x 10⁻⁸ M  
      pH = 7.1  
      pOH = 6.9
   d) [OH⁻] = 9.9 x 10⁻¹¹ M  
      pH = 4  
      pOH = 10
   e) [H⁺] = 3.22 x 10⁻³ M 
      pH = 2.49  
      pOH = 11.51
   f) [OH⁻] = 5.76 x 10⁻² M  
      pH = 12.76  
      pOH = 1.24

10) Calculate [H⁺] and [OH⁻] for the following solutions:
   a) a solution with pH = 11
      [H⁺] = 1 x 10⁻¹¹ M  
      [OH⁻] = 1 x 10⁻³ M
   b) a solution with pH = 8.5
      [H⁺] = 3.2 x 10⁻⁹ M  
      [OH⁻] = 3.2 x 10⁻⁶ M
   c) a solution with pH = 2.45
      [H⁺] = 3.55 x 10⁻³ M 
      [OH⁻] = 2.82 x 10⁻¹² M
   d) a solution with pOH = 7
      [H⁺] = 1 x 10⁻⁷ M  
      [OH⁻] = 1 x 10⁻⁷ M
   e) a solution with pOH = 1.3
      [H⁺] = 2.0 x 10⁻¹³ M  
      [OH⁻] = 5.0 x 10⁻² M
   f) a solution with pOH = 12.6
      [H⁺] = 3.98 x 10⁻² M  
      [OH⁻] = 2.51 x 10⁻¹³ M