UNIT SEVEN

PROBLEM SET

Do not cheat by copying the work of another person, or by allowing another person to copy your answers. Cheating results in a 0% grade for both parties involved.

Signature______________________________ Date_________

In the event any or all of this Problem Set is assessed for a grade, it must be signed and dated in order to receive a grade. The work shall be your own.

Problem Sets are generally not accepted late. Late assignments are 50% off.
Ch 7 WS 8: Empirical Formulas

1. Determine the empirical formula from the compound formula. Circle the ionic compounds.

   a) $\text{C}_6\text{H}_6$  
   b) $\text{C}_2\text{H}_6$  
   c) $\text{C}_3\text{H}_8$  
   d) $\text{Fe}_3(\text{CO})_9$  
   e) $\text{C}_2\text{H}_4\text{O}_2$  
   f) $\text{N}_2\text{H}_4$  
   g) $\text{CaBr}_2$  
   h) $\text{C}_2\text{H}_2$  
   i) $\text{Na}_2\text{SO}_4$  
   j) $\text{C}_6\text{H}_5\text{N}$  
   k) $\text{P}_4\text{O}_{10}$  
   l) $\text{Re}_2\text{Cl}_6$  
   m) $\text{Se}_3\text{O}_9$  
   n) $\text{LiCl}$

Determine the empirical formula of the following compounds based on the percent compositions

1. 92.24 % C; 7.76 % H

2. 86.7% carbon, 14.3% hydrogen?

3. 49.99 % C; 5.61 % H; 44.40 % O

Answers: 2= CH , 3= CH$_2$ , 4= C$_3$H$_4$O$_2$
Chapter 7 Worksheet 9: More Empirical Formulas

What is the empirical formula (lowest whole number ratio) of the below compounds

1. 52.7% potassium, 47.3% chlorine

2. 43.6% phosphorus, 56.4% oxygen

3. 71.0% potassium, 29% sulfur

4. 37.0% iron, 20.5% phosphorus, 42.5% oxygen

5. 32.4% sodium, 22.6% sulfur, 45.1% oxygen

Answers: 1: KCl, 2=P2O5, 3=K2S, 4=FePO4, 5=Na2SO4
Chapter 7 Worksheet 10: Determining Molecular Formulas

1. The empirical formula of a compound is NO. Its molar mass is 60. g/mol. What is the molecular formula?

2. The empirical formula of a compound is CH₂. Its molecular mass is 84 g/mol. What is the molecular formula?

3. An unknown compound is found to contain 49.2% phosphorus and 50.8% oxygen. The molar mass is determined to be 125.94 g/mole. What is the compound’s molecular formula?

4. A molecular compound contains 40.0% carbon, 6.7% hydrogen, and 53.3% oxygen. Its molar mass is 180.18 g/mol. What is the compound’s molecular formula?

5. A molecular compound contains 52.2% carbon, 13.1% hydrogen, and 34.7% oxygen. Its molar mass is 46.07 g/mol. What is the compound’s molecular formula?

Answers: 1: N₂O₂, 2: C₆H₁₂, 3: P₂O₄, 4: C₆H₁₂O₆, 5: C₂H₆O
Ch 18 WS 1 Molarity Calculation Worksheet

Molarity = \( \frac{\text{moles of solute}}{\text{liters of solution}} \)

1. What is the molarity of a solution in which 58 grams of NaCl are dissolved in 2.1 liter of solution?

2. What is the molarity of a solution in which 10.0 g of AgNO₃ is dissolved in 500. mL of solution?

3. How many grams of KNO₃ should be used to prepare 2.00 L of a 0.750 M solution?

4. To what volume should 5.0 g of KCl be diluted in order to prepare a 0.25 M solution?

5. How many grams of CuSO₄•5H₂O are needed to prepare 100. mL of a 0.10 M solution?

Answers to molarity problems: 1=0.47M, 2=0.118M, 3=152 g, 4=0.27 L, 5=2.5 g
Ch 18 WS 2 Dilution Practice Problems

1. A stock solution of 1.00 M NaCl is available. How many milliliters are needed to make 100.0 mL of 0.750 M?

2. What volume of 0.250 M KCl is needed to make 100.0 mL of 0.100 M solution?

3. Concentrated H$_2$SO$_4$ is 18.0 M. What volume is needed to make 2.00 L of 1.00 M solution?

4. Concentrated HCl is 12.0 M. What volume is needed to make 2.00 L of 1.00 M solution?

5. A 0.500 M solution is to be diluted to 500.0 mL of a 0.150 M solution. How many mL of the 0.500 M solution are required?

6. A stock solution of 10.0 M NaOH is prepared. From this solution, you need to make 250.0 mL of 0.375 M solution. How many mL will be required?

7. 2.00 L of 0.800 M NaNO$_3$ must be prepared from a solution known to be 1.50 M in concentration. How many mL are required?

Answers to Dilutions: 1=75mL, 2=40.0mL, 3=0.111L, 4=0.167L, 5=150.mL, 6=9.38mL, 7=1070 mL
Key equations: \( M = \text{mol/L} \quad M_1V_1 = M_2V_2 \)

1. What is the molarity of 4.5 grams of \( \text{CaCl}_2 \) in 400 mL of solution? (Ans = 0.10M)

2. What is the final concentration if 60.0 mL of a 6.0 M solution is diluted to 800 mL? (Ans = 0.45 M)

3. How many grams of NaOH are needed to prepare 4.0 liters of a 1.2 M solution? (Ans = 190 g)

4. What is the concentration of 15 mL of 6.0 M HCl diluted to 2.0 liters? (Ans = 0.045 M)

5. What volume, L, of solution is required to prepare a 3.0 M solution from 29 grams of lithium fluoride? (Ans = 0.37 L)

6. What is the molarity of a solution containing 8.9 grams of NaNO\(_3\) in 250 mL of solution? (Ans = 0.42 M)
7. How many milliliters of 0.80 Molar KMnO$_4$ are needed to provide 0.240 mol of KMnO$_4$? (Ans = 300 mL)

8. A solution contains 16 grams of Na$_2$SO$_4$ dissolved in enough water to make 4.0 liters of solution. What is the molarity of the solution? (Ans = 0.028 M)

9. A 0.50 L solution of MgSO$_4$ contains 0.25 mole of the solute. What is the approximate molarity of the solution? (Ans = 0.50 M)

10. How many mL of 0.25 M Cu(NO$_3$)$_2$ are required to prepare 25 mL of 0.050 M Cu(NO$_3$)$_2$? (Ans = 5.0 mL)
Molarity Calculation Worksheet

Name _________________________  Block ____

Chemistry - Becke

Molarity = \( \frac{\text{moles of solute}}{\text{liters of solution}} \)

1. How many grams of AgNO\(_3\) are required to make 25 mL of a 0.80M solution?

2. What volume of 0.15M SrSO\(_4\) can be made from 23.1 grams?

3. Find the molarity of a 2.50 L solution containing 7 g of potassium fluoride.

4. How many grams of aluminum chloride are required to make 0.50 L of a 1.0M solution?

5. Find the molarity of an 85 mL solution containing 2.6 g of ZnCl\(_2\).

6. Find the molarity of a 750 mL solution containing 20.0 g of lithium bromide.

Answers: 1) 3.4 g, 2) 0.84 L, 3) 0.048 M, 4) 67 g, 5) 0.22 M, 6) 0.31 M
\[ M_1 V_1 = M_2 V_2 \]

1. A solution of 1.00 M NaCl is available. How many milliliters are needed to make 100.0 mL of 0.750 M?

2. What volume of 0.250 M KCl is needed to make 100.0 mL of 0.100 M solution?

3. Concentrated H\(_2\)SO\(_4\) is 18.0 M. What volume is needed to make 2.00 L of 1.00 M solution?

4. Concentrated HCl is 12.0 M. What volume is needed to make 2.00 L of 1.00 M solution?

5. A 0.500 M solution is to be diluted to 500.0 mL of a 0.150 M solution. How many mL of the 0.500 M solution are required?

6. A stock solution of 10.0 M NaOH is prepared. From this solution, you need to make 250.0 mL of 0.375 M solution. How many mL will be required?

7. 2.00 L of 0.800 M NaNO\(_3\) must be prepared from a solution known to be 1.50 M in concentration. How many mL are required?

Answers: 1)75 mL, 2) 40.0 mL, 3) 0.111 L, 4) 0.167 L, 5) 150 mL, 6) 9.38 L, 7) 1070 mL
An acid is a substance that creates the hydronium ion, \( \text{H}_3\text{O}^+ \), in solution. The concentration of hydronium is represented by \([\text{H}_3\text{O}^+]\) and this value determines the pH of a solution. The pH is calculated by taking the logarithm of \([\text{H}_3\text{O}^+]\) and changing the sign: \( \text{pH} = -\log [\text{H}_3\text{O}^+] \). A neutral solution has a pH of 7, while acidic solutions have pH values less than 7. Basic or alkaline solutions have pH values greater than 7.

### Solve the following problems. Show all work.

1. Find the pH of a solution with \([\text{H}_3\text{O}^+]\) = 2.3 × 10\(^{-4}\) M. Is the solution acidic or basic?
2. Find the pH of a solution with \([\text{H}_3\text{O}^+]\) = 7.42 × 10\(^{-11}\) M. Is the solution acidic or basic?
3. Vinegar (acetic acid) has a pH of about 2.4. Determine the \([\text{H}_3\text{O}^+]\) for vinegar. Is it acidic or basic?
4. Baking soda has a pH of about 8.15. Find the \([\text{H}_3\text{O}^+]\) for a baking soda solution. Is it acidic or basic?
5. Find the pOH for a solution with \([\text{OH}^-]\) = 5.5 × 10\(^{-3}\) M. Is the solution acidic or basic?
6. Find the pOH for a solution with \([\text{OH}^-]\) = 3.71 × 10\(^{-6}\) M. Is the solution acidic or basic?
7. A 0.05 M solution of NaOH contains 0.05 M OH\(^-\). Find the pOH of this solution and convert to pH.
8. In a blood sample \([\text{OH}^-]\) = 3.2 × 10\(^{-7}\) M. Find the pOH of blood and convert to pH.
9. The pOH of household ammonia is 2.5. Determine the \([\text{OH}^-]\) in ammonia. Is the solution acidic or basic?
10. Lemon juice has a pH of about 3.6. Determine the \([\text{H}_3\text{O}^+]\) in lemon juice. Is it acidic or basic?
**Acids generate H⁺ (H₃O⁺) ions in water.** They are molecular compounds that dissociate in water. Usually the formula begins with an H. A hydrogen bonded to carbon is never acidic. The hydrogen will not dissociate from the molecule in water. **Bases generate hydroxide ions in water.** They are ionic compounds with a hydroxide polyatomic. However, ammonia, NH₃, also produces hydroxide in water through the reaction NH₃ + H₂O → NH₄OH. Many compounds are neither Bronsted acids nor bases. This includes most molecular compounds and ionic compounds that do not produce a hydroxide ion in water.

Identify the following compounds as acids, bases, or neither by making a check mark in the appropriate column.

<table>
<thead>
<tr>
<th>Compound</th>
<th>Acid</th>
<th>Base</th>
<th>Neither</th>
</tr>
</thead>
<tbody>
<tr>
<td>HCl</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>KOH</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NaBr</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NH₃</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ba(OH)₂</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H₂C₂H₃O₂</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CH₄</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H₂SO₄</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mg(OH)₂</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

**pH and pOH**

The pH of a solution indicates how acidic or basic that solution is.

- **pH range of 0 – 7 acidic**
- **pH = exactly 7 neutral**
- **pH range of 7-14 basic**

Since \([\text{H}^+][\text{OH}^-] = 1 \times 10^{-14}\) at 25°C, if \([\text{H}^+]\) is known, the \([\text{OH}^-]\) can be calculated and vice versa.

\[
pH = -\log[\text{H}^+] \quad \text{So if } [\text{H}^+] = 1 \times 10^{-6} \text{ M, } pH = 6
\]

\[
pOH = -\log[\text{OH}^-] \quad \text{So if } [\text{OH}^-] = 1 \times 10^{-8} \text{ M, } pOH = 8
\]

Together, **pH + pOH = 14**

Complete the following chart

<table>
<thead>
<tr>
<th>([\text{H}^+])</th>
<th>pH</th>
<th>([\text{OH}^-])</th>
<th>pOH</th>
<th>Acid or Basic</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. 1 x 10⁻⁷ M</td>
<td>5</td>
<td>1 x 10⁻⁹ M</td>
<td>9</td>
<td>Acid</td>
</tr>
<tr>
<td>2.</td>
<td>7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td></td>
<td>1 x 10⁻⁴ M</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. 1 x 10⁻² M</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td></td>
<td></td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>6.</td>
<td></td>
<td></td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>7.</td>
<td></td>
<td>1 x 10⁻⁷ M</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. 1 x 10⁻¹¹</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9.</td>
<td></td>
<td></td>
<td>13</td>
<td></td>
</tr>
<tr>
<td>10.</td>
<td></td>
<td></td>
<td>6</td>
<td></td>
</tr>
</tbody>
</table>
Acids are compounds that can donate the hydrogen ion, H\(^+\). When the formula for an acid is written the symbol for this hydrogen generally appears at the beginning of the formula. For example the formula for hydrochloric acid is written HCl and the formula for phosphoric acid is H\(_3\)PO\(_4\). Notice that both formulas begin with the letter H. In both cases the acid is made of a hydrogen ion (or hydrogen ions) and a negative ion, known as the anion.

The name for an acid is based on the name of the anion. If the anion ends with the letters –ide, the acid is named one way while acids containing anions that end with –ate use a different rule. Remember that monatomic anions typically end with –ide. The rules for naming acids are summarized below.

### Naming Acids

<table>
<thead>
<tr>
<th>Anion called (root) ide</th>
<th>Acid called hydro (root) ic acid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Example: sulfide, S(^2-)</td>
<td>Example: hydrosulfuric acid, H(_2)S</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Anion called (root) ate</th>
<th>Acid called (root) ic acid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Example: chlorate, ClO(_3)(^-)</td>
<td>Example: chloric acid, HClO(_3)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Anion called (root) ite</th>
<th>Acid called (root) ous acid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Example: chlorite, ClO(_2)(^-)</td>
<td>Example: chlorous acid, HClO(_2)</td>
</tr>
</tbody>
</table>

### Examples

1. Write the chemical formula for: sulfurous acid.
   - this acid contains the hydrogen ion and the sulfite ion: H\(^+\) SO\(_3\)\(^2-\)
   - create a neutral compound from these ions: H\(^+\) SO\(_3\)\(^2-\) H\(_2\)SO\(_3\)

2. Name the following acid: H\(_2\)CO\(_3\).
   - this acid contains the hydrogen ion and the carbonate ion: H\(^+\) CO\(_3\)\(^2-\)
   - the name of the negative ion is carbonate, therefore the acid is called carbonic acid.

### Fill in the following table with the missing information.

<table>
<thead>
<tr>
<th>Formula</th>
<th>Cation</th>
<th>Formula for anion</th>
<th>Name of anion</th>
<th>Name of Acid</th>
</tr>
</thead>
<tbody>
<tr>
<td>HCl</td>
<td>H(^+)</td>
<td>Cl(^-)</td>
<td>chloride</td>
<td></td>
</tr>
<tr>
<td>HNO(_3)</td>
<td>H(^+)</td>
<td>F(^-)</td>
<td>nitrate</td>
<td></td>
</tr>
<tr>
<td>H(_2)SO(_4)</td>
<td>H(^+)</td>
<td>SO(_4)(^2-)</td>
<td>carbonate</td>
<td></td>
</tr>
<tr>
<td>H(_2)SO(_3)</td>
<td>H(^+)</td>
<td>ClO(_3)(^-)</td>
<td>chloric acid</td>
<td></td>
</tr>
<tr>
<td>H(_2)C(_2)O(_4)</td>
<td>H(^+)</td>
<td>ClO(_3)(^-)</td>
<td>phosphate</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>oxalate</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>AsO(_4)(^3-)</td>
<td>arsenate</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>nitrous acid</td>
<td></td>
</tr>
</tbody>
</table>
An acid is defined as a substance that donates a proton (written H⁺) while a base is the substance that receives a proton. Typically the chemical formula can be used to determine the acid, because it will begin with the symbol H. For example in the following equation HCl is the acid and it donates a proton to water.

\[ \text{HCl} + \text{H}_2\text{O} \rightarrow \text{H}_3\text{O}^+ + \text{Cl}^- \]

In this reaction the HCl is the acid, while the H₂O acts as the base. This creates two new products: hydronium, H₃O⁺, and the chloride ion, Cl⁻.

Some acids have the ability to donate two or three protons and these are known as diprotic or triprotic acids respectively. For these acids each successive step of hydrogen donation is represented with its own equation. Consider the diprotic acid called carbonic acid, H₂CO₃.

**First step:**

\[ \text{H}_2\text{CO}_3 + \text{H}_2\text{O} \rightarrow \text{H}_3\text{O}^+ + \text{HCO}_3^- \]

**Second step:**

\[ \text{HCO}_3^- + \text{H}_2\text{O} \rightarrow \text{H}_3\text{O}^+ + \text{CO}_3^{2-} \]

**Rewrite each equation and label the acid and the base in each reaction.**

1. \( \text{NH}_3 + \text{H}_2\text{O} \rightarrow \text{NH}_4^+ + \text{OH}^- \)
2. \( \text{HI} + \text{OH}^- \rightarrow \Gamma + \text{H}_2\text{O} \)
3. \( \text{HCO}_3^- + \text{HNO}_3 \rightarrow \text{H}_2\text{CO}_3 + \text{NO}_3^- \)
4. \( \text{H}_2\text{O} + \text{CN}^- \rightarrow \text{HCN} + \text{OH}^- \)
5. \( \text{OH}^- + \text{NH}_4^+ \rightarrow \text{H}_2\text{O} + \text{NH}_3 \)
6. \( \text{H}_2\text{SO}_4 + \text{PO}_4^{3-} \rightarrow \text{HPO}_4^{2-} + \text{HSO}_4^- \)

**Fill in the following table.**

<table>
<thead>
<tr>
<th></th>
<th>Acid</th>
<th>Base</th>
<th>Equation</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>HNO₃</td>
<td>OH⁻</td>
<td>HNO₃ + OH⁻ ( \rightarrow ) H₂O + NO₃⁻</td>
</tr>
<tr>
<td>8</td>
<td>HCN</td>
<td></td>
<td>CH₃NH₂ + H₂O ( \rightarrow ) OH⁻ + CH₃NH₃⁺</td>
</tr>
<tr>
<td>9</td>
<td>HBr</td>
<td></td>
<td>HCN + H₂O ( \rightarrow ) H₃O⁺ + CN⁻</td>
</tr>
<tr>
<td>10</td>
<td>H₂C₂O₄⁻</td>
<td>NH₃</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>HPO₄²⁻</td>
<td></td>
<td>OH⁻ + H₂S ( \rightarrow ) H₂O + HS⁻</td>
</tr>
<tr>
<td>12</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td></td>
<td>OH⁻</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>HClO</td>
<td>NH₃</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>HSO₄⁻</td>
<td>CO₃²⁻</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>1.</td>
<td>0.01 M HCl</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>0.001 M HNO\textsubscript{3}</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>0.0001 M NaOH</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>0.00010 M HBr</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>0.1 M KOH</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6.</td>
<td>0.0050 M Ca(OH)\textsubscript{2}</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

And a little subatomic particle review:

- How many protons are in Calcium-42? ______
- How many electrons are in Ca\textsuperscript{2+}? _____
- How many neutrons are in \textsuperscript{32}P? ______
- How many neutrons are in \textsuperscript{66}\textsubscript{30}Zn? ______
- How many valence electrons does silicon have? ______
- How many valence electrons do the halogens have? ______
- When chlorine becomes an ion, it has the same number of total electrons as ____.
Ch 20 WS 3 pH calculations and polyatomic review

1. The pH of an aqueous solution that is 1 x 10^{-3} M HCl is _______.

2. The pH of an aqueous solution that contains 1 x 10^{-4} M HBr is _______.

3. The pH of an aqueous solution that contains 1 x 10^{-2} M NaOH is _______.

4. The pH of an aqueous solution with a pOH of 8 is _______

5. Indicate whether the solution is acidic or basic or neutral

<table>
<thead>
<tr>
<th>Solution</th>
<th>Acidic</th>
<th>Basic</th>
<th>Neutral</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH = 2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>pH = 9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>pOH = 6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>pOH = 10</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 x 10^{-4} M NaOH</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 x 10^{-6} M HCl</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>[OH^{-}] = 1 x 10^{-9} M</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>[H^{+}] = 1 x 10^{-4} M</td>
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</tr>
</tbody>
</table>

6. Convert the following pH values to [H^{+}] or [OH^{-}] concentration

   Example: pH = 7, [H^{+}] = 1 x 10^{-7} M

   pH = 5, [H^{+}] = __________
   pOH = 6, [OH^{-}] = __________
   pOH = 11, [H^{+}] = __________
   pH = 2, [OH^{-}] = __________

Polyatomic Review
What is the formula and charge of the following polyatomic ions:

_________ammonium  __________acetate
_________carbonate  __________hydrogen carbonate
_________phosphate  __________nitrate
_________hydroxide  __________sulfate
Ch 20 WS 4 pH and neutralization reactions

1. What polyatomic ion is found in ionic compound bases? ________________

2. What does pH measure? ________________________________

3. pH + pOH always = ____________ at 25°C in aqueous solutions.

4. [H+] x [OH-] always = ______________ at 25° C in aqueous solutions.

5. The hydrogen ion concentration is 1 x 10^-6. What is the pH of the solution? ____________

6. The hydroxide ion concentration is 1 x 10^-3. What is the pH of the solution? ________.

7. The pH of a 0.010 molar aqueous solution of hydrochloric acid, HCl, would equal__________.

8. Indicate whether the solution is acidic or basic.

   pH = 8_____________________  pH = 2____________________

   [H+] = 1 x 10^-4 Molar ____________  [OH^-] = 1 x 10^-6 Molar ____________

   1 x 10^-6 Molar HCl ______________  1 x 10^-6 Molar NaOH ______________

9. Convert the following pH values to [H+] or [OH-] concentration:

   Example:  pH = 7, [H+] concentration = 1 x 10^-7 M

   pH = 10, [H+] concentration = ________________

   pOH = 4, [OH^-] concentration = ________________

   pOH = 3, [H+] concentration = ________________

   pH = 6, [OH^-] concentration = ________________

10. Circle the base in the following neutralization reactions. Box the salt if applicable.

    HBr+ LiOH → LiBr + H₂O

    Mg(OH)₂ + 2HNO₃  ⇌ Mg(NO₃)₂ + 2H₂O

    H₂SO₄ +2 KOH  ⇌ 2H₂O + K₂SO₄

    NH₃ + HCl  ⇌ NH₄⁺ + Cl⁻

11. What is the name of the salt formed by the neutralization of hydrochloric acid and sodium hydroxide?
An acid is neutralized by a base. If the concentration and volume of the base are accurately known, the concentration or the molar mass of an acid can be determined. The concentration of an unknown acid is equal to the moles of acid per liter of acid. The molar mass of an acid is the grams of acid per mole of acid.

**Examples**

When 1.04 g of a monoprotic unknown acid (HA) is titrated with 0.300 M NaOH it takes 75.21 mL of base to neutralize the acid. Determine the molar mass of the unknown acid.

\[
\text{HA} + \text{NaOH} \rightarrow \text{NaA} + \text{H}_2\text{O}
\]

- begin with units of L on the bottom: (liters will be converted to moles, which are on the bottom of molar mass)

\[
\frac{1}{0.07521 \text{ L NaOH}} \times \frac{1 \text{ mol NaOH}}{0.300 \text{ mol NaOH}} \times \frac{1 \text{ mol HA}}{1 \text{ mol NaOH}} \times \frac{1.04 \text{ g HA}}{1} = 46.1 \text{ grams HA} \text{ mol HA}^{-1}
\]

An unknown diprotic acid (H₂A) with a volume of 10.0 mL is titrated with 165 mL of 0.15 M KOH. Find the concentration of the acid in mol/L.

\[
\text{H}_2\text{A} + \text{KOH} \rightarrow \text{K}_2\text{A} + 2\text{H}_2\text{O}
\]

- begin with units of L on the top: (liters will be converted to moles, which are on the top of the molarity units)

\[
\frac{0.165 \text{ L KOH}}{1} \times \frac{0.15 \text{ mol KOH}}{1 \text{ mol KOH}} \times \frac{1 \text{ mol H}_2\text{A}}{2 \text{ mol KOH}} \times \frac{1}{0.0100 \text{ L H}_2\text{A}} = 1.2 \text{ mol H}_2\text{A} \text{ L H}_2\text{A}^{-1}
\]

**Answer the following questions. Show all work and report answers with units.**

1. Lactic acid, a chemical responsible for muscle fatigue, is a monoprotic acid. When 0.578 g of lactic acid is titrated with 0.206 M NaOH, a volume of 31.11 mL of NaOH is used. What is the molar mass of lactic acid?

   \[
   \text{HA} + \text{NaOH} \rightarrow \text{NaA} + \text{H}_2\text{O}
   \]

2. A volume of 25.0 mL of nitric acid, HNO₃, is titrated with 0.12 M NaOH. To completely neutralize the acid 10 mL of NaOH must be added. Find the concentration (mol/L) of the nitric acid.

   \[
   \text{HNO}_3 + \text{NaOH} \rightarrow \text{NaNO}_3 + \text{H}_2\text{O}
   \]

3. Malonic acid is a diprotic acid used in the production of pharmaceuticals. A 0.965 g sample of malonic acid requires 45.91 mL of 0.404 M LiOH to be neutralized. Determine the molar mass (g/mol) for malonic acid.

   \[
   \text{H}_2\text{A} + 2 \text{LiOH} \rightarrow \text{Li}_2\text{A} + 2\text{H}_2\text{O}
   \]

4. To find the molarity of sulfuric acid, H₂SO₄ it is titrated with 0.75 M KOH. It requires 328.4 mL of KOH to neutralize a 40.00 mL sample of sulfuric acid. Calculate the concentration (mol/L) of the sulfuric acid.

   \[
   \text{H}_2\text{SO}_4 + 2 \text{ KOH} \rightarrow \text{K}_2\text{SO}_4 + 2\text{H}_2\text{O}
   \]

5. Boric acid is a triprotic acid that is used as an ant and roach killer. A 1.42-g sample of boric acid is neutralized by 157 mL of 0.4388 M NaOH. Determine the molar mass (g/mol) for boric acid.

   \[
   \text{H}_3\text{A} + 3 \text{NaOH} \rightarrow \text{Na}_3\text{A} + 3\text{H}_2\text{O}
   \]

6. Tartaric acid, H₂C₄H₆O₆, is neutralized with 0.100 M NaOH. A sample of 3.0 g of tartaric acid reacts with 45 mL of base. How concentrated is the base?

   \[
   \text{H}_2\text{C}_4\text{H}_6\text{O}_6 + 2 \text{NaOH} \rightarrow \text{Na}_3\text{C}_4\text{H}_6\text{O}_6 + 2\text{H}_2\text{O}
   \]
1. Predict the products of the following neutralization reactions. Do not worry about balancing

HF + KOH → ________ + _________

\( \text{H}_2\text{SO}_4 + \text{NaOH} \rightarrow ________ + _________ \)

\( \text{H}_3\text{PO}_4 + \text{KOH} \rightarrow ________ + _________ \)

\( \text{HCl} + \text{Ca(OH)}_2 \rightarrow ________ + _________ \)

2. A 15 mL sample of acetic acid, HCH\(_3\)COO, is titrated with 5.0 mL of 0.25 M NaOH to its phenolphthalein endpoint. What is the concentration of the acetic acid? (Ans = 0.083 M)

\( \text{H}_3\text{CH}_3\text{COO} + \text{NaOH} \rightarrow \text{H}_2\text{O} + \text{NaCH}_3\text{COO} \)

3. 20 mL of 0.080 M KOH is required to titrate 34 mL of nitric acid, to its phenolphthalein endpoint. What is the molarity of the nitric acid? (Ans = 0.047 M)

\( \text{HNO}_3 + \text{KOH} \rightarrow \text{KNO}_3 + \text{H}_2\text{O} \)

4. How many mLs of 3.0 M NaOH is needed to completely neutralize 1200 mLs of 0.200 M HCl? (Ans = 80. mL)

\( \text{NaOH} + \text{HCl} \rightarrow \text{NaCl} + \text{H}_2\text{O} \)

5. How many moles of HCl are required to completely neutralize 0.55 moles of Ba(OH)\(_2\)? (Ans = 1.1 mol)

\( \text{Ba(OH)}_2 + 2\text{HCl} \rightarrow 2\text{H}_2\text{O} + \text{BaCl}_2 \)
Practice Acid-Base Titration Problems

1. A 15 ml sample of Acetic Acid, HCH₃COO, is titrated with 5.0 mL of 0.25 M NaOH to its phenolphthalein endpoint. What is the concentration of the acetic acid? (Ans = 0.083 M)

   \[ \text{HCH}_3\text{COO} + \text{NaOH} \rightarrow \text{H}_2\text{O} + \text{NaCH}_3\text{COO} \]

2. 20. mL of 0.080 M KOH is required to titrate 34 mL of hydrobromic acid, HBr, to its phenolphthalein endpoint. What is the molarity of the sulfuric acid?

   \[ \text{KOH(aq)} + \text{HBr(aq)} \rightarrow \text{KBr(aq)} + \text{H}_2\text{O(l)} \]

3. A 94 mL sample of citric acid, H₃C₆H₅O₇, solution (example=orange juice) is titrated to the phenolphthalein endpoint using 7.0 mL of 0.010 M NaOH. What is the concentration of the citric acid in the orange juice? (Ans = 0.00025 M)

   \[ \text{H}_3\text{C}_6\text{H}_5\text{O}_7 + 3\text{NaOH} \rightarrow \text{Na}_3\text{C}_6\text{H}_5\text{O}_7 + 3\text{H}_2\text{O} \]

4. A 25 mL sample of 0.040 molar aqueous barium hydroxide, Ba(OH)₂, was titrated to its phenolphthalein endpoint using 0.080 M HCl. How many mLs of the HCl solution were required? (Ans = 25 mL)

   \[ \text{Ba(OH)}_2 + 2\text{HCl} \rightarrow 2\text{H}_2\text{O} + \text{BaCl}_2 \]
1. What polyatomic ion is found in ionic compound bases? __________________

2. What does pH measure? ________________________________

3. pH + pOH always = ____________ at 25°C in aqueous solutions.

4. [H+] x [OH-] always = _______________ at 25°C in aqueous solutions.

5. The hydrogen ion concentration is $1 \times 10^{-6}$. What is the pH of the solution? ____________

6. The hydroxide ion concentration is $1 \times 10^{-3}$. What is the pH of the solution? ____________.

7. The pH of a 0.010 molar aqueous solution of hydrochloric acid, HCl, would equal ________.

8. Indicate whether the solution is acidic or basic.

\[
\begin{align*}
\text{pH} &= 8 \quad [\text{H}^+] = 1 \times 10^{-4} \text{ Molar} \\
\text{pH} &= 2 \quad [\text{OH}^-] = 1 \times 10^{-6} \text{ Molar} \\
1 \times 10^{-6} \text{ Molar HCl} &\quad 1 \times 10^{-6} \text{ Molar NaOH} \\
\end{align*}
\]

9. Convert the following pH values to [H+] or [OH-] concentration:

   Example: pH = 7, [H+] concentration = $1 \times 10^{-7}$ M

   pH = 10, [H+] concentration = _________________

   pOH = 4, [OH-] concentration = _________________

   pOH = 3, [H+] concentration = _________________

   pH = 6, [OH-] concentration = _________________

10. Circle the base in the following neutralization reactions. Box the salt if applicable.

   HBr + LiOH → LiBr + H₂O

   Mg(OH)₂ + 2HNO₃ ⇌ Mg(NO₃)₂ + 2H₂O

   H₂SO₄ + 2 KOH ⇌ 2H₂O + K₂SO₄

   NH₃ + HCl ⇌ NH₄⁺ + Cl⁻

11. What is the name of the salt formed by the neutralization of hydrochloric acid and sodium hydroxide?
Conjugate Acid Base Pairs
Chem Worksheet 19-2

An acid is defined as a proton (H⁺) donor while a base is a proton acceptor. The substance that is produced after an acid has donated its proton is called the conjugate base while the substance formed when a base accepts a proton is called the conjugate acid. The conjugate acid can donate a proton to the conjugate base, to reform the original reactants in the reverse reaction.

\[
\text{HF} + \text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{O}^+ + \text{F}^-
\]

In the reaction above HF is the acid and H₂O is the base. The HF has given a proton to the H₂O, forming H₃O⁺ and F⁻. Since the product H₃O⁺ can donate a proton back to F⁻ it is labeled the conjugate acid, while the F⁻ is the conjugate base.

Example

Write an equation that shows NH₃ reacting with HCl. Label the acid, base, and conjugate acid and conjugate base.

- Write reactants and transfer a proton from the acid to the base:

\[
\text{NH}_3 + \text{HCl} \rightleftharpoons \text{NH}_4^+ + \text{Cl}^-
\]

Rewrite each equation. Identify the acid, the base, the conjugate acid, and the conjugate base in each of the equations.

1. HCl + NH₃ → NH₄⁺ + Cl⁻
2. OH⁻ + HCN → H₂O + CN⁻
3. PO₄³⁻ + HNO₃ → NO₃⁻ + HPO₄²⁻
4. HCO₃⁻ + HCl → H₂CO₃ + Cl⁻
5. HCO₃⁻ + OH⁻ → H₂O + CO₃²⁻
6. NH₄⁺ + H₂O → NH₃ + H₃O⁺
7. C₂O₄²⁻ + HC₂H₃O₂ → HC₂O₄⁻ + C₂H₃O₂⁻
8. HPO₄²⁻ + H₂O → OH⁻ + H₂PO₄⁻

Fill in the following table.

<table>
<thead>
<tr>
<th>Acid</th>
<th>Base</th>
<th>Conjugate Acid</th>
<th>Conjugate Base</th>
<th>Equation</th>
</tr>
</thead>
<tbody>
<tr>
<td>9 HNO₂</td>
<td>H₂O</td>
<td></td>
<td></td>
<td>( \text{HNO}_2 + \text{H}_2\text{O} \rightarrow \text{NO}_2^- + \text{H}_3\text{O}^+ )</td>
</tr>
<tr>
<td>10 H₂O</td>
<td>F⁻</td>
<td>HF</td>
<td>OH⁻</td>
<td>( \text{NH}_3 + \text{HCN} \rightarrow \text{NH}_4^+ + \text{CN}^- )</td>
</tr>
<tr>
<td>11</td>
<td>H₂O</td>
<td></td>
<td>ClO₃⁻</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>H₂O</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13 HSO₄⁻</td>
<td>PO₄³⁻</td>
<td></td>
<td></td>
<td>( \text{S}^{2-} + \text{H}_2\text{O} \rightarrow \text{OH}^- + \text{HS}^- )</td>
</tr>
<tr>
<td>15 HCO₂H</td>
<td>OH⁻</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

16. Write an equation that shows the reaction of ammonia, NH₃ with hydrobromic acid, HBr. Label the acid, the base, the conjugate acid, and the conjugate base.
17. Write an equation that shows the reaction of phosphate ion, PO₄³⁻, reacting with hydronium ion, H₃O⁺. Label the acid, the base, the conjugate acid, and the conjugate base.
18. Write an equation that shows the reaction of hydrogen sulfide, HS⁻ with hydroxide ion, OH⁻. Label the acid, the base, the conjugate acid, and the conjugate base.