1. A 5.00 mL H$_2$SO$_4$ solution required 7.84mL of 0.100M NaOH to titrate to the phenolphthalein endpoint. What is the concentration of the H$_2$SO$_4$ solution?

$$\text{H}_2\text{SO}_4 + 2\text{NaOH} \rightarrow \text{Na}_2\text{SO}_4 + 2\text{H}_2\text{O}$$

$$0.0100\text{M NaOH} \times (0.00784\text{L}) = 0.000784\text{moles NaOH}$$

$$\text{mols H}_2\text{SO}_4 = \frac{1}{2} \text{moles NaOH} \quad \frac{0.000784}{2} = 0.000392\text{ moles H}_2\text{SO}_4$$

$$M = \frac{0.000392\text{ moles HA}}{0.005\text{ L}} = 0.0784\text{ M H}_2\text{SO}_4$$

2. The pH of 0.10M acetic acid was measured; then 0.1154g of sodium acetate was added to the acid, and the pH was measured again. Afterward, 0.3027g of sodium acetate was added to the salt and the acid mixture, and the pH was also measured. The following chart depicts the concentrations of each ion and acid in the solution:

$$\text{CH}_3\text{COOH} \leftrightarrow \text{H}^+ + \text{CH}_3\text{COO}^-$$

a. Fill in the blanks in the table and show calculations.

$$\text{pH} = -\log [\text{H}^+]$$

<table>
<thead>
<tr>
<th>[NaC$_2$H$_3$O$_2$]</th>
<th>pH</th>
<th>[H$^+$]</th>
<th>[C$_2$H$_3$O$_2$]</th>
<th>[HC$_2$H$_3$O$_2$]</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>1.72</td>
<td>10$^{-pH}$</td>
<td>.019</td>
<td>.019</td>
</tr>
<tr>
<td></td>
<td></td>
<td>.019</td>
<td>.1 - .019 = .08095</td>
<td></td>
</tr>
<tr>
<td>.14</td>
<td>-log .010 = 2.00</td>
<td>0.010</td>
<td>0.15</td>
<td>.1 - .01 = .09</td>
</tr>
<tr>
<td>0.51</td>
<td>4.00</td>
<td>0.00010</td>
<td>0.5101</td>
<td>0.1 - 0.00010 = .0999</td>
</tr>
</tbody>
</table>

$$[\text{C}_2\text{H}_3\text{O}_2^-] = [\text{NaAc}] + [\text{H}^+]$$

b. Calculate the Ka for each solution and the average Ka.

$$\text{Ka} = \frac{[\text{H}^+] [\text{A}^-]}{[\text{HA}]}$$

1. 4.5 E -3
2. 1.7E -2
3. 5.1 E -4
3. At a particular temperature, assume that the equilibrium constant is $K = 100.0$ for the reaction:

$$H_2(g) + F_2(g) \rightarrow 2HF(g)$$

a. Provide the expression for $K$.

$$K = \frac{[HF]^2}{[H_2][F_2]}$$

b. A reaction mixture is prepared in a 1.000 liter flask with 4.7 moles each of hydrogen and fluorine gas plus for some unexplained reason 1.2 moles of HF. What is the equilibrium concentration of hydrogen from this initial mixture?

\[
\begin{array}{c|c|c|c}
 & H_2 & F_2 & \rightarrow 2HF \\
I & 4.7 & 4.7 & 1.2 \\
C & -x & -x & +2x \\
E & 4.7-x & 4.7-x & 1.2 + 2x \\
\end{array}
\]

$$K = 100.0 = \frac{(1.2 + 2x)^2}{(4.7-x)^2}$$

Square root both sides to get:

$$10 = \frac{1.2 + 2x}{(4.7-x)}$$

$$10 (4.7 – x) = 1.2 + 2x$$

$$47 – 10x = 1.2 + 2x \quad \Rightarrow \quad 45.8 = 12x \quad \Rightarrow \quad 3.8 = x$$

$$[H_2] = 4.7 – x = 4.7 – 3.8 = 0.9 \text{ M}$$

4. A 20mL sample of a solution of NaOH reacts with 0.3641g KHP, a primary standard. What is a primary standard? Calculate the molarity of NaOH. (KHP = 204.2 g/mol)

**primary standard** = doesn’t react with $H_2O, \text{ air}, \text{ etc.}$$

Molarity = ?

moles NaOH = moles KHP  1:1 ratio

$$\frac{0.3641 \text{ g KHP} \times 1 \text{ mol}}{204.2 \text{ g}} \times \frac{1}{1} = \frac{0.00178 \text{ mol NaOH}}{0.020 \text{ L}} = 0.08915 \text{ M} = 0.09 \text{ M NaOH}$$
5. Give the following for the molecule:
   \[ \text{CH}_3\text{CH}_2\text{CHBrCHBrCH}_3 \]

i) The Lewis dot structure (include bond angles)

```
    H    H    Br   Br   H
   |       |      |     |     |                      All angles are 109.5°
H—C—C—C—C—C—H
   |       |      |      |      |
H    H    H    H    H
```

ii) Name?

five carbons in a chain so pent. no double bonds so pentane. Molecule is numbered so that the bromines have the lowest number. Bromines are on the 2\textsuperscript{nd} and 3\textsuperscript{rd} carbons. 2,3-dibromo-pentane

iii) Hybridization? All carbons are sp\textsuperscript{3}.

iv) Number of pi bonds? zero

v) 3-D drawing?

5a. Give the following for the molecule: CCl\textsubscript{4}

i) Lewis dot structure:

```
                   Cl
    Cl — C — Cl
          |     |
    Cl
```

ii) Hybridization? carbon is sp\textsuperscript{3}.

iii) number of pi bonds? zero

iv) Angles? All 109.5°.
6. Consider the reaction:

\[ \text{CH}_4(g) + \text{H}_2\text{O}(g) \rightarrow \text{CO}(g) + 3\text{H}_2(g) \]

<table>
<thead>
<tr>
<th>Substance</th>
<th>( \Delta H^\circ_f ) (KJ/mol)</th>
<th>( \Delta G^\circ_f ) (KJ/mol)</th>
<th>( \Delta S^\circ_f ) (JK(^{-1})mol(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH(_4)(g)</td>
<td>-64.81</td>
<td>-50.75</td>
<td>186.2</td>
</tr>
<tr>
<td>H(_2)O(g)</td>
<td>-231.8</td>
<td>-228.6</td>
<td>188.7</td>
</tr>
<tr>
<td>CO(g)</td>
<td>-100.5</td>
<td>-137.2</td>
<td>197.6</td>
</tr>
<tr>
<td>H(_2)(g)</td>
<td>0.00</td>
<td>0.00</td>
<td>130.6</td>
</tr>
</tbody>
</table>

a) Calculate \( \Delta H^\circ \) (include units).

\[ \Delta H = \Delta \text{products} - \Delta \text{reactants} = (-100.5 + (3\times0)) - (-64.81 + -231.8) = (-100.5) - (-296.61) = 196.11 \text{ KJ} = 196.1 \text{ KJ} \]

b) Calculate \( \Delta S^\circ \) (include units).

\[ \Delta S = (197.6 + (3\times130.6)) - (186.2 + 188.7) = (589.4) - (374.9) = 214.5 \text{ J/K/mol} \]

c) Calculate \( \Delta G^\circ \) (include units).

\[ \Delta G = (-137.2) - (-279.35) = 142.15 \text{ KJ/mol} \]

d) Indicate if it is spontaneous.

\( \Delta G \) is positive; therefore not spontaneous

7. How much energy is absorbed by 3.50kg of titanium in going from 25°C to 82.0°C if the specific heat of titanium is 0.594J/g°C?

\[ \Delta H = mC\Delta T = (3500g) \times (0.594 \text{ J/g°C}) \times (82.0°C - 25°C) = 118503\text{ J} = 1.18E5 \text{ J or 118 KJ} \]
9. How do the following factors affect the reaction:
\[ \text{SrCO}_3(s) \rightarrow \text{SrO(s) + CO}_2(g) \]
a) Addition of \text{SrCO}_3(s) 
\text{no effect}

b) Increase in pressure? 
\text{shifts left because less moles of gas}

c) Addition of \text{CO}_2(g) 
\text{shifts left because you added products}

10. A solution is prepared by adding 2.0mL of 0.2M HCl to 10.0mL of 0.20M NH\_3 and diluting to 50.0mL. Calculate the pH of the solution. (\text{K}_b\text{ for ammonia is }1.8E-5)

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

\[ \begin{array}{c|c|c|c|c}
   & \text{HCl} & \text{NH}_3 & \leftrightarrow & \text{NH}_4^+ & \text{Cl}^- \\
   I & (.002L)(.2M) & (.2M)(0.010L) & 0 & 0 & .002 mol \\
   C & -.0004 & -.0004 & +.0004 & +.0004 & .002 mol \\
   E & 0 & .0016 & .0004 & .0004 & \text{weak base conj acid neutral} \\
\end{array} \]

\[ [\text{NH}_3] = .0016/.050 = .032 \]

\[ \text{pOH} = \text{pK}_b + \log (\text{conj acid/base}) \]
\[ = (-\log \text{K}_b) + \log (.008/.032) \]
\[ = 4.14 \]

\[ 14 - \text{pOH} = \text{pH} \]
\[ 14-4.14 = 9.86 \]

\[ [\text{NH}_4^+] = .0004/.050 = .008 \]

11. A galvanic cell: \text{Co}_2^+ (1.0M)\_\text{Ag}^+ (0.20M) \_\text{Ag} , is allowed to operate and deliver a direct current.

Given:
\[ \text{Co}^{2+} + 2e^- \rightarrow \text{Co} \quad -0.28 \text{ V} \quad \rightarrow \text{most negative, therefore is oxidized} \]
\[ \text{Ag}^+ + e^- \rightarrow \text{Ag} \quad 0.80 \text{ V} \]

a) Which electrode is the anode? \text{cobalt}

b) What is the potential of this cell?
\[
\begin{align*}
\text{Co} & \rightarrow \text{Co}^{2+} + 2e^- + .28 \text{ V} \\
\text{Ag}^+ + e^- & \rightarrow \text{Ag} + .80 \text{ V} \\
& \quad - 1.08 \text{ V}
\end{align*}
\]

12. For the following organic molecules, provide the structural formulas, Lewis formula, 3-D model sketch, number of pi bonds:
   a) 3-bromo-1-pentene
   
   ![3-bromo-1-pentene_structure]

   1 pi bond

   ![3-bromo-1-pentene_3D_model]

   b) tetrachloromethane
   
   ![tetrachloromethane_structure]

13. 40.0mL of 0.25M NH₃ is titrated with 0.3M HCl. (Kₘₚ for NH₃ is 1.8E-5) Find the pH at:

a) The initial point BEFORE and HCl is added: pH = ?

\[
\begin{array}{c|c|c|c|c|}
R & \text{NH}_3 & + & \text{H}_2\text{O} & \leftrightarrow & \text{NH}_4^+ & + & \text{OH}^- \\
I & .25M & 0 & 0 & 0 \\
C & -x & 0 & +x & +x \\
E & .25 - x & +x & +x \\
\end{array}
\]

\[
K_b = [\text{NH}_4^+][\text{OH}^-] = \frac{x^2}{x} = 1.8\text{E-5}
\]
\[
\text{[NH}_3\text{]} \quad 0.25 - x
\]

\[
x = 2.12 \times 10^{-3} = [\text{OH}^-]
\]

\[
p\text{OH} = 2.67 \quad \text{pH} = 11.32
\]
b) After 10 mL HCl is added: pH = ?

40.0 mL of 0.25 M NH₃ is titrated with 0.30 M HCl  
\[ K_b \text{ for } NH_3 = 1.8 \times 10^{-5} \]

<table>
<thead>
<tr>
<th>R</th>
<th>HCl</th>
<th>+</th>
<th>NH₃</th>
<th>↔</th>
<th>NH₄⁺</th>
<th>+</th>
<th>Cl⁻</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>.003mol</td>
<td></td>
<td>.01mol</td>
<td>0</td>
<td></td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>C</td>
<td>-.003</td>
<td></td>
<td>-.003</td>
<td>+.003</td>
<td>+.003</td>
<td></td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>0</td>
<td></td>
<td>.01-.003</td>
<td>.003</td>
<td>.003</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

base | conj salt | neutral |

\[ [NH_3] = \frac{.007}{.050} = .14 \text{M} \]
\[ \text{pOH} = -\log 1.8 \times 10^{-5} + \log (\frac{.06}{.14}) \]
\[ [NH_4^+] = \frac{.003}{.050} = .06 \text{M} \]
\[ \text{pH} = 9.63 \]

14. What is the rate law?

<table>
<thead>
<tr>
<th>Exp</th>
<th>[A]</th>
<th>[B]</th>
<th>Initial Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>.50</td>
<td>1.50</td>
<td>4.2e-3</td>
</tr>
<tr>
<td>2</td>
<td>1.50</td>
<td>1.50</td>
<td>1.3e-2</td>
</tr>
<tr>
<td>3</td>
<td>3.00</td>
<td>3.00</td>
<td>5.2e-2</td>
</tr>
</tbody>
</table>

Compare experiment 2 to 1. A is tripled and the initial rate triples.

Since \([A]^x = \text{rate}\), then \(3^x = 3\)  \(x = 1\)

Compare experiment 3 and 2. You know that \(\text{rate} = [A]^x [B]^y\) so

\[
\frac{5.2 \times 10^{-2}}{1.3 \times 10^{-2}} = k \frac{3^y}{1.5^y} \quad 4 = 2^x \times 2^y \quad 4 = 2^y \quad y = 1
\]

The initial rate quadruples when both reactants are doubled.

The rate equation is \(\text{rate} = k [A] [B]\)

The overall order of the reaction is 2.

15. Absorption of a solution is 0.235. The path length is 2.5 cm and the concentration is 0.75 M. What is the extinction coefficient?

\[ A = \varepsilon bc \]

\(A\) is the absorbance
\(b\) is the path length
\(c\) is the concentration
\(\varepsilon\) is the extinction coefficient

\[ \varepsilon = \frac{A}{bc} = \frac{.235}{(2.5 \text{ cm})(.75 \text{ M})} = .1253 \text{ mol/cm*L} \]