1. (12 points) Give an example (either name or chemical formula) for:
   A Strong Acid
   \( \text{HCl, HNO}_3, \text{H}_2\text{SO}_4, \text{or HClO}_4 \)

   A Weak Acid
   \( \text{CH}_3\text{COOH, NH}_4^+ \text{ and others} \)

   A Weak Base
   \( \text{NH}_3, \text{CH}_3\text{COO}^- \text{ and others} \)

   A Strong base
   \( \text{NaOH, KOH, Ca(OH)}_2 \text{ and others} \)

   A Polyprotic Acid
   \( \text{H}_2\text{SO}_4, \text{H}_3\text{PO}_4, \text{H}_2\text{CO}_3 \text{ and others} \)

   An Acidic Salt
   \( \text{NH}_4\text{Cl, Al(NO}_3)_3 \text{ and others} \)

2. (6 points) Calculate the pH of a 0.56 mM solution of HCl

   \[ 0.56 \text{ mM} \times 1 \times 10^{-3} \text{ moles/mM} = 5.6 \times 10^{-4} \text{ M} \]

   Strong acid so \([\text{H}^+] = 5.6 \times 10^{-4} \text{ M}\)

   \[ \text{pH} = -\log[\text{H}^+] = -\log(5.6 \times 10^{-4} \text{ M}) \]

   \[ = -\log(-3.2518) \]

   \[ = 3.25 \]
3. (7 points) Calculate the pH of a 1x10^{-8} M solution of NaOH

Strong base so [NaOH] = [OH^-]

[OH^-] = 1x10^{-8}

pOH = -log (1x10^{-8}) = 8

pH = 14 - pOH = 6

But hold it. This is an acid pH and we are dealing with a base! Something is fishy. What is Dr. Z. Trying to pull ???

Ahhh... Remember that there are two sources of OH^-, the base and the autoionization of water itself. Usually we don’t deal with the water because its contribution is so small, but in this case, the base is so very dilute that we have to include it.

The quick and dirty answer [OH^-] from water = 1x10^{-7}, [OH^-] from base = 1x10^{-8}

Add them together and get [OH^-] = 1.1x10^{-7}; pOH = -log( 1.1x10^{-7}) = 6.96

pH = 14 - 6.96 = 7.04 which is basic so this is a better answer!

4A. (8 points) I have a weak acid that is 1.5% ionized when it is at a concentration of .025M. What is the K_a of this acid?

\[ \%_{_{\text{ionization}}} = \frac{[A^-]}{[HA] + [A^-]} \times 100\% \]

\[ 1.5 = \frac{x}{.025} \times 100; \quad X = 1.5(.025) / 100 = 3.75 \times 10^{-4} \]

\[ K_a = \frac{[H^+][A^-]}{[HA]}; \quad [H^+] = [A^-]; \quad HA = .025 - 3.75 \times 10^{-4} \]

\[ K_a = \frac{(3.75 \times 10^{-4})^2}{.025 - 3.75 \times 10^{-4}} = 5.71 \times 10^{-6} \]

B. (2 points) What will happen to the pH of this solution if the acid is diluted further? (Will it go up, remain the same, or go down?)

pH will go up

C. (2 points) What will happen to the % ionization of the acid if the acid is diluted further? (Will it go up, remain the same, or go down?)

% ionization will go up
5. (12 points) Predict the pH of the following salts.  
(Fill in A for acidic, B for basic or N for neutral)

\[ \text{KCl } \_N\_ \]
\[ \text{Cr(NO}_3\text{)}_6 \_A\_ \]
\[ \text{NaCH}_3\text{COO } _B\_\_ \]
\[ \text{NH}_4\text{NO}_3 \_A\_ \]
\[ \text{SeO}_2 \_A\_ \]
\[ \text{SnO}_2 \_A \text{ or } B\_ \]  
(Sn\textsuperscript{+4} would be acidic, but the O\textsuperscript{-} would be basic so it is hard to tell which would dominate)

6. (12 points) Define the following:

Nucleophile
A species that seeks + charge to donate electrons to, hence a Lewis Base

Lewis acid
An electron acceptor

Bronsted-Lowry Base
A proton acceptor

Free Energy
\( G \), Energy available to do work or a measure of the spontaneity of a process

Entropy, a thermodynamic measure of randomness

The second law of thermodynamics
In any spontaneous process the randomness of the universe must increase.

7. (13 points) Calculate \( \Delta S_{\text{reaction}} \) for the reaction
\[ 2\text{C}_2\text{H}_2\text{(g)} + 5\text{O}_2\text{(g)} \rightarrow 4\text{CO}_2\text{(g)} + 2\text{H}_2\text{O}(g) \]

Given the following data:

<table>
<thead>
<tr>
<th>Substance</th>
<th>( S^\circ ) (J/K\text{-}mol)</th>
</tr>
</thead>
<tbody>
<tr>
<td>\text{C}_2\text{H}_2\text{(g)}</td>
<td>201</td>
</tr>
<tr>
<td>\text{O}_2\text{(g)}</td>
<td>161</td>
</tr>
<tr>
<td>\text{O}_2\text{(g)}</td>
<td>205</td>
</tr>
<tr>
<td>\text{O}_2\text{(g)}</td>
<td>239</td>
</tr>
<tr>
<td>\text{CO}\text{(g)}</td>
<td>198</td>
</tr>
<tr>
<td>\text{CO}_2\text{(g)}</td>
<td>214</td>
</tr>
<tr>
<td>\text{H}_2\text{O(l)}</td>
<td>70</td>
</tr>
<tr>
<td>\text{H}_2\text{O(g)}</td>
<td>189</td>
</tr>
</tbody>
</table>

\[
\Delta S_{\text{reaction}} = \sum n_p S_p - \sum n_r S_r
\]

\[
= [4(214) + 2(189)] - [2(201) + 5(205)]
\]

\[
= 856 + 378 - 402 - 1025
\]

\[
= -194 \text{ J} / \text{K} \cdot \text{mol}
\]
8. (12 points) Given that the chemical reaction $\text{N}_2\text{O}_4(l) \rightleftharpoons \text{N}_2\text{O}_4(g)$ has a $\Delta H^\circ$ of 30.0 kJ/mole and a $\Delta S^\circ$ of 95 J/K·mol, what is the normal boiling point for $\text{N}_2\text{O}_4$?

At the normal boiling point the liquid and the gas will be at equilibrium, so $\Delta G=0$

$$\Delta G = \Delta H - T \Delta S$$

$$0 = 30,000 \text{ J/mol} - X(95 \text{ J/K·mol})$$

$$X(95) = 30,000$$

$$X = \frac{30,000 \text{ J/mol}}{95 \text{ J/K·mol}} = 316 \text{ K}$$

9A. (10 points) Calculate $\Delta G^\circ$ for the reaction $2\text{C}_2\text{H}_2(g) + 5\text{O}_2(g) \rightleftharpoons 4\text{CO}_2(g) + 2\text{H}_2\text{O}(g)$

Given the following data

<table>
<thead>
<tr>
<th>Substance</th>
<th>$\Delta G^\circ$ (kJ/mol)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\text{C}_2\text{H}_2(g)$</td>
<td>209</td>
</tr>
<tr>
<td>$\text{O}(g)$</td>
<td>232</td>
</tr>
<tr>
<td>$\text{O}_2(g)$</td>
<td>0</td>
</tr>
<tr>
<td>$\text{O}_3(g)$</td>
<td>163</td>
</tr>
<tr>
<td>$\text{CO}(g)$</td>
<td>-137</td>
</tr>
<tr>
<td>$\text{CO}_2(g)$</td>
<td>-394</td>
</tr>
<tr>
<td>$\text{H}_2\text{O}(l)$</td>
<td>-237</td>
</tr>
<tr>
<td>$\text{H}_2\text{O}(g)$</td>
<td>-229</td>
</tr>
</tbody>
</table>

$$\Delta G_{\text{rxn}} = \sum n_p \Delta G_p - \sum n_l \Delta G_l^\circ$$

$$= [4(-394) + 2(-229)] - [2(209) - 5(0)]$$

$$= -1576 - 458 - 418$$

$$= -2452 \text{ kJ/mol}$$

9B (3 points) Is this reaction spontaneous?

$\Delta G$ is negative, so the reaction is spontaneous