FIRST EXAM

Closed book, one page of notes allowed.

Answer all questions. Please state any additional assumptions you made, and show all work. You are welcome to use a graphical method of solution if it is appropriate.

Miscellaneous Information:

| R = 1.987 cal/mole°K = 8.314 J/mole°K |
| Absolute zero = -273.15°C |
| 1 joule = 0.239 calories |
| 540 calories = 1 Big Mac |

1. (50%) What is the pH of a $10^{-2.00}$ M solution of Sodium fluoride (NaF)? Calculate this for each of the three conditions below (obviously, the ionic strength will never be zero for this solution, but let's assume the ideal case for part “a” and “b” anyway).
   a. 25°C, I = 0
   b. 100°C, I = 0
   c. 25°C, I = 0.25

2. (40%) What is the complete composition of a 1-liter volume of water containing $10^{-2}$ M of ammonium bisulfide (NH₄HS)? Approximate values (± 0.2 log units) will suffice.
3. (10%) True/False. Mark each one of the following statements with either a "T" or an "F".

a. _____ Water is an amphoteric substance.
b. _____ A nano gram is equivalent to one-thousandths of a milligram.
c. _____ The third most common gas in the atmosphere is argon.
d. _____ Non-carbonate hardness only exists in waters with alkalinites less than their total hardness.
e. _____ Mass defects are directly proportional to nuclear binding energy.
f. _____ The Guntelberg Approximation says that activity coefficients are dependent on charge and ionic strength, but not on ion size.
g. _____ The reactivity of neutral species is unaffected by changes in ionic strength.
h. _____ Increases in ionic strength cause a increase in the pKa of an acid, if the fully-protonated form of the acid is an uncharged species.
i. _____ The standard assumption used for calculating the pH of buffer solutions is that [H+] and [OH-] are negligible.
j. _____ The value of $\alpha_0$ plus $\alpha_1$ must always equal unity for a monoprotic acid.
## Selected Acidity Constants (Aqueous Solution, 25°C, \( I = 0 \))

<table>
<thead>
<tr>
<th>NAME</th>
<th>FORMULA</th>
<th>( pK_a )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perchloric acid</td>
<td>( \text{HClO}_4 = \text{H}^+ + \text{ClO}_4^- )</td>
<td>-7</td>
</tr>
<tr>
<td>Hydrochloric acid</td>
<td>( \text{HCl} = \text{H}^+ + \text{Cl}^- )</td>
<td>-3</td>
</tr>
<tr>
<td>Sulfuric acid</td>
<td>( \text{H}_2\text{SO}_4 = \text{H}^+ + \text{HSO}_4^- )</td>
<td>-3</td>
</tr>
<tr>
<td>Nitric acid</td>
<td>( \text{HNO}_3 = \text{H}^+ + \text{NO}_3^- )</td>
<td>0</td>
</tr>
<tr>
<td>Hydronium ion</td>
<td>( \text{H}_3\text{O}^+ = \text{H}^+ + \text{H}_2\text{O} )</td>
<td>0</td>
</tr>
<tr>
<td>Trichloroacetic acid</td>
<td>( \text{CCl}_3\text{COOH} = \text{H}^+ + \text{CCl}_3\text{COO}^- )</td>
<td>0.70</td>
</tr>
<tr>
<td>Iodic acid</td>
<td>( \text{HIO}_3 = \text{H}^+ + \text{IO}_3^- )</td>
<td>0.8</td>
</tr>
<tr>
<td>Bisulfate ion</td>
<td>( \text{HSO}_4^- = \text{H}^+ + \text{SO}_4^{2-} )</td>
<td>2</td>
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<tr>
<td>Phosphoric acid</td>
<td>( \text{H}_3\text{PO}_4 = \text{H}^+ + \text{H}_2\text{PO}_4^- )</td>
<td>2.15</td>
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<tr>
<td>o-Phthalic acid</td>
<td>( \text{C}_6\text{H}_4(\text{COOH})_2 = \text{H}^+ + \text{C}_6\text{H}_4(\text{COOH})\text{COO}^- )</td>
<td>2.89 &amp; 5.51</td>
</tr>
<tr>
<td>Citric acid</td>
<td>( \text{C}_3\text{H}_5\text{O}(\text{COOH})_3 = \text{H}^+ + \text{C}_3\text{H}_5\text{O}(\text{COOH})_2\text{COO}^- )</td>
<td>3.14 &amp; 4.77 &amp; 6.4</td>
</tr>
<tr>
<td>Hydrofluoric acid</td>
<td>( \text{HF} = \text{H}^+ + \text{F}^- )</td>
<td>3.2</td>
</tr>
<tr>
<td>Aspartic acid</td>
<td>( \text{C}_2\text{H}_6\text{N}(\text{COOH})_2 = \text{H}^+ + \text{C}_2\text{H}_6\text{N}(\text{COOH})\text{COO}^- )</td>
<td>3.86 &amp; 9.82</td>
</tr>
<tr>
<td>m-Hydroxybenzoic acid</td>
<td>( \text{C}_6\text{H}_4(\text{OH})\text{COOH} = \text{H}^+ + \text{C}_6\text{H}_4(\text{OH})\text{COO}^- )</td>
<td>4.06 &amp; 9.92</td>
</tr>
<tr>
<td>p-Hydroxybenzoic acid</td>
<td>( \text{C}_6\text{H}_4(\text{OH})\text{COOH} = \text{H}^+ + \text{C}_6\text{H}_4(\text{OH})\text{COO}^- )</td>
<td>4.48 &amp; 9.32</td>
</tr>
<tr>
<td>Nitrous acid</td>
<td>( \text{HNO}_2 = \text{H}^+ + \text{NO}_2^- )</td>
<td>4.5</td>
</tr>
<tr>
<td>Acetic acid</td>
<td>( \text{CH}_3\text{COOH} = \text{H}^+ + \text{CH}_3\text{COO}^- )</td>
<td>4.75</td>
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<tr>
<td>Propionic acid</td>
<td>( \text{C}_2\text{H}_5\text{COOH} = \text{H}^+ + \text{C}_2\text{H}_5\text{COO}^- )</td>
<td>4.87</td>
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<tr>
<td>Carbonic acid</td>
<td>( \text{H}_2\text{CO}_3 = \text{H}^+ + \text{HCO}_3^- )</td>
<td>6.35 &amp; 10.33</td>
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<tr>
<td>Hydrogen sulfide</td>
<td>( \text{H}_2\text{S} = \text{H}^+ + \text{HS}^- )</td>
<td>7.02 &amp; 13.9</td>
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<tr>
<td>Dihydrogen phosphate</td>
<td>( \text{H}_2\text{PO}_4^- = \text{H}^+ + \text{HPO}_4^{2-} )</td>
<td>7.2</td>
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<tr>
<td>Hypochlorous acid</td>
<td>( \text{HOCl} = \text{H}^+ + \text{OCl}^- )</td>
<td>7.5</td>
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<tr>
<td>Boric acid</td>
<td>( \text{B(OH)}_3 + \text{H}_2\text{O} = \text{H}^+ + \text{B(OH)}_4^- )</td>
<td>9.2 &amp; 12.7,13.8</td>
</tr>
<tr>
<td>Ammonium ion</td>
<td>( \text{NH}_4^+ = \text{H}^+ + \text{NH}_3 )</td>
<td>9.24</td>
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<tr>
<td>Hydrocyanic acid</td>
<td>( \text{HCN} = \text{H}^+ + \text{CN}^- )</td>
<td>9.3</td>
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<tr>
<td>p-Hydroxybenzoic acid</td>
<td>( \text{C}_6\text{H}_4(\text{OH})\text{COO}^- = \text{H}^+ + \text{C}_6\text{H}_4(\text{OH})\text{COO}^- )</td>
<td>9.32</td>
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<tr>
<td>Phenol</td>
<td>( \text{C}_6\text{H}_5\text{OH} = \text{H}^+ + \text{C}_6\text{H}_5\text{O}^- )</td>
<td>9.9</td>
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<tr>
<td>m-Hydroxybenzoic acid</td>
<td>( \text{C}_6\text{H}_4(\text{OH})\text{COO}^- = \text{H}^+ + \text{C}_6\text{H}_4(\text{OH})\text{COO}^- )</td>
<td>9.92</td>
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<td>Bicarbonate ion</td>
<td>( \text{HCO}_3^- = \text{H}^+ + \text{CO}_3^{-2} )</td>
<td>10.33</td>
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<td>Monohydrogen phosphate</td>
<td>( \text{HPO}_4^{2-} = \text{H}^+ + \text{PO}_4^{3-} )</td>
<td>12.3</td>
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<td>Bisulfide ion</td>
<td>( \text{HS}^- = \text{H}^+ + \text{S}^{-2} )</td>
<td>13.9</td>
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<tr>
<td>Water</td>
<td>( \text{H}_2\text{O} = \text{H}^+ + \text{OH}^- )</td>
<td>14.00</td>
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<td>Ammonia</td>
<td>( \text{NH}_3 = \text{H}^+ + \text{NH}_2^- )</td>
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<td>Methane</td>
<td>( \text{CH}_4 = \text{H}^+ + \text{CH}_3^- )</td>
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<tr>
<td>Species</td>
<td>$\Delta H_f^o$ kcal/mole</td>
<td>$\Delta G_f^o$ kcal/mole</td>
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<td>----------------------------</td>
<td>--------------------------</td>
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<tr>
<td>Ca$^{2+}$(aq)</td>
<td>-129.77</td>
<td>-132.18</td>
</tr>
<tr>
<td>CaCO$_3$(s), calcite</td>
<td>-288.45</td>
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<td>CaO (s)</td>
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<td>C(s), graphite</td>
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<td>CO$_2$(g)</td>
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<td>CO$_2$(aq)</td>
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<td>CH$_4$ (g)</td>
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<td>H$_2$CO$_3$ (aq)</td>
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<td>HCO$_3^-$ (aq)</td>
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<td>CH$_3$COO$^-$, acetate</td>
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<td>H$^+$ (aq)</td>
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<td>H$_2$ (g)</td>
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<td>HF (aq)</td>
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<td>F$^-$ (aq)</td>
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<td>Fe$^{2+}$ (aq)</td>
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<td>Fe$^{3+}$ (aq)</td>
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<td>Fe(OH)$_3$ (s)</td>
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<td>NO$_3^-$ (aq)</td>
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<td>NH$_3$ (g)</td>
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<td>NH$_3$ (aq)</td>
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<td>NH$_4^+$ (aq)</td>
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<td>O$_2$ (aq)</td>
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<td>O$_2$ (g)</td>
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<td>OH$^-$ (aq)</td>
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<td>H$_2$O (g)</td>
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<td>H$_2$O (l)</td>
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<td>PO$_4^{3-}$ (aq)</td>
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<td>-243.50</td>
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<td>HPO$_4^{2-}$ (aq)</td>
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<td>H$_2$PO$_4^-$ (aq)</td>
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<td>H$_2$PO$_2$ (aq)</td>
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<td>SO$_4^{2-}$</td>
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<td>HS$^-$</td>
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<td>H$_2$S(g)</td>
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<td>H$_2$S(aq)</td>
<td>-9.4</td>
<td>-6.54</td>
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