Question 1
8 Points
How many moles of potassium fluoride should be added to 2.5 L of a 0.197 M hydrofluoric acid (HF) solution to prepare a buffer with a pH of 2.210?

\[ \text{pH} = \text{pK}_a + \log \frac{[F^-]}{[HF]} \]

\[ 2.210 = 3.143 + \log \frac{[F^-]}{[HF]} \]

\[ \frac{[F^-]}{[HF]} = 0.117 \]

\[ [F^-] = 0.023 \]

\[ 0.023 \text{ mol.L}^{-1} \times 2.5 \text{ L} = 0.058 \]

\[ \frac{[\text{Base}]}{[\text{Acid}]} = 0.117 \]

Moles of KF = 0.058

Question 2
8 Points
An aqueous solution contains 0.393 M ammonia. How many moles of hydroiodic acid would have to be added to 250 mL of this solution to prepare a buffer with a pH of 9.020?

\[ \text{pH} = \text{pK}_a + \log \frac{[\text{NH}_3]}{[\text{NH}_4^+]} \]

\[ 9.020 = 9.255 + \log \frac{[\text{NH}_3]}{[\text{NH}_4^+]} \]

\[ \frac{[\text{NH}_3]}{[\text{NH}_4^+]} = 0.582 \]

\[ \frac{0.392 - x}{x} = 0.582 \]

\[ x = 0.248 \]

\[ 0.248 \text{ mol.L}^{-1} \times 0.250 \text{ L} = 0.062 \text{ mol NH}_4^+ \]

\[ 0.062 \text{ mol HI} \]

\[ \frac{[\text{Base}]}{[\text{Acid}]} = 0.582 \]

Moles of HI = 0.062

Question 3
8 Points
Assuming 100K_a < 0.1 then the area where the pH can be determined by:

1) \(-\log_{10}(\text{K}_a \times 0.1^{0.5})\)  \(\text{A}\)
2) \(-\log_{10}(\text{K}_a)\)  \(\text{C}\)
3) \(-\log_{10}(\text{K}_b \times 0.05^{0.5})\)  \(\text{B}\)
4) Circle the area on the curve in which the pH can be determined by:

\[ \text{pH} = \text{pK}_a + \log_{10}(\left[\text{A}^-\right]/[\text{HA}]) \]
Question 4  
6 Points

Determine the equilibrium concentration of hydroxide ion in a saturated manganese(II) hydroxide solution.

\[ \text{Mn(OH)}_2(s) \rightleftharpoons \text{Mn}^{2+} + 2 \text{OH}^- \]

\[ \begin{array}{ccc}
\text{I} & 0 & 0 \\
\text{C} & -s & s \\
\text{E} & -s & s \\
\end{array} \]

\[ s(2s)^2 = 4.6 \times 10^{-14} \]
\[ s = 2.26 \times 10^{-5} \]

\[ K_{sp} = [\text{Mn}^{2+}][\text{OH}^-]^2 \]

\[ 4.51 \times 10^{-5} \text{ M} \]

Question 5  
5 Points

The maximum amount of barium phosphate that will dissolve in a 0.279 M ammonium phosphate solution is

\[ \text{Ba}_2(\text{PO}_4)_3(s) \rightleftharpoons 3 \text{Ba}^{2+} + 2 \text{PO}_4^{3-} \]

\[ \begin{array}{ccc}
\text{I} & 0 & 0.279 \\
\text{C} & -s & 3s \\
\text{E} & -s & 3s \\
\text{A} & -s & 3s \\
\end{array} \]

\[ (3s)^3(0.279)^2 = 1.3 \times 10^{-29} \]
\[ s = 1.84 \times 10^{-10} \]

\[ K_{sp} = [\text{Ba}^{2+}]^3[\text{PO}_4^{3-}]^2 \]

\[ 1.84 \times 10^{-10} \text{ M} \]

Question 6  
8 Points

Each of the insoluble salts below are put into 0.10 M hydroiodic acid solution. Do you expect their solubility to be: more, less, or about the same as in a pure water solution?

1. Lead iodide  
   B
2. Barium fluoride  
   A
3. Calcium sulfite  
   A
4. Silver bromide  
   C

Question 7  
10 Points

Predict whether \( \Delta S \) for each reaction would be greater than zero, less than zero, or too close to zero to decide.

A. \( 2\text{H}_2\text{O}_2(\text{l}) = 2\text{H}_2\text{O}(\text{l}) + \text{O}_2(\text{g}) \)
   \[ 1 \]
   1. Greater than 0

B. \( 2\text{HBr}(\text{g}) + \text{Cl}_2(\text{g}) = 2\text{HCl}(\text{g}) + \text{Br}_2(\text{g}) \)
   \[ 3 \]
   2. Less than 0

C. \( \text{I}_2(\text{g}) + \text{Cl}_2(\text{g}) = 2\text{ICl}(\text{g}) \)
   \[ 3 \]
   2. Less than 0

D. \( 2\text{CO}(\text{g}) + 2\text{NO}(\text{g}) = 2\text{CO}_2(\text{g}) + \text{N}_2(\text{g}) \)
   \[ 2 \]
   3. Too close to tell

E. \( \text{PCl}_5(\text{g}) = \text{PCl}_3(\text{g}) + \text{Cl}_2(\text{g}) \)
   \[ 1 \]
Question 8 8 Points
When 15.0 mL of a $2.52 \times 10^{-4}$ M silver acetate solution is combined with 15.0 mL of a $2.70 \times 10^{-4}$ M potassium hydroxide solution does a precipitate form?

For these conditions the Reaction Quotient, $Q$, is equal to

$$Q = \frac{[Ag^+][OH^-]}{[AgOH]}$$

$$Q = \frac{2.52 \times 10^{-4}(0.015)}{2.70 \times 10^{-4}(0.015)} = 1.70 \times 10^{-8}$$

$Q < K_{sp}$

Yes  No

Question 9 4 Points
Using standard absolute entropies at 298K, calculate the entropy change for the following reaction:

$$H_2S(g) + 2H_2O(l) = 3H_2(g) + SO_2(g)$$

$$\Delta S^\circ = 3S^\circ H_2(g) + S^\circ SO_2(g) - S^\circ H_2S(g) - 2S^\circ H_2O(l)$$

$$\Delta S^\circ = 3(131) + 248 - 206 - 2(70) = 295 \text{ J.K}^{-1}$$

Question 10 6 Points
Consider the reaction:

$$2N_2(g) + O_2(g) = 2N_2O(g)$$

Using standard thermodynamic data at 298K, calculate the entropy change for the surroundings when 1 mole of $O_2(g)$ reacts at standard conditions:

$$\Delta H_{Rxn} = 2\Delta H_f N_2O(g) - 2\Delta H_f N_2(g) - \Delta H_f O_2(g)$$

$$\Delta H_{Rxn} = 2(82) - 2(0) - 0 = 164 \text{ kJ/mol}$$

$$\Delta S_{Surf} = -164,000/298 = -550 \text{ J.mol}^{-1}.K^{-1}$$

Question 11 6 Points
For the reaction:

$$2H_2S(g) + 3O_2(g) = 2H_2O(g) + 2SO_2(g)$$

$\Delta H^\circ = -1036 \text{ kJ}$ and $\Delta S^\circ = -153 \text{ J/K}.$

Assuming that $\Delta H^\circ$ and $\Delta S^\circ$ are independent of temperature, determine the maximum amount of work that could be done when 1.8 moles of $H_2S(g)$ react at 326 K and 1 atm.

$$\Delta G_{Rxn} = \Delta H - T\Delta S$$

$$\Delta G_{Rxn} = -1036 -326(-0.153) = -986 \text{ kJ}$$

Work = 986 kJ/2 mol $H_2S$

$$887 \text{ kJ}$$
Question 12
12 Points
Without doing any calculations, match the following thermodynamic properties with their appropriate numerical sign for the following reactions.

A. \( \text{N}_2(g) + 3\text{H}_2(g) = 2\text{NH}_3(g) \) **Exothermic**

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<th>Property</th>
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<td>( \Delta G_{\text{Rxn}} )</td>
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<td>( \Delta S_{\text{Universe}} )</td>
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<td>= 0</td>
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<td>&lt; 0 low T, &gt; 0 high T</td>
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</table>
|                |         | < 0 low T, > 0 high T               

B. \( 2\text{H}_2\text{O}(g) + 2\text{SO}_2(g) = 2\text{H}_2\text{S}(g) + 3\text{O}_2(g) \) **Endothermic**

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Question 13
5 Points

\( 2\text{NH}_3(g) + 2\text{O}_2(g) = \text{N}_2\text{O}(g) + 3\text{H}_2\text{O}(l) \) \( \Delta H^\circ = -683\text{kJ} \) \( \Delta S^\circ = -366\text{J/K} \)

**Above** or **below** what temperature would the above reactions \( \Delta G^\circ \) be less than zero?

\[
\Delta H^\circ - T\Delta S^\circ = 0
\]
\[
-683,000 - T(-366) = 0
\]
\[
366T = 683,000
\]

**Above/Below** **Below**

1866 K

Question 14
6 Points

Consider the reaction: \( \text{N}_2(g) + 3\text{H}_2(g) = 2\text{NH}_3(g) \)

Calculate \( \Delta G \) for this reaction at 298.15K if the pressure of \( \text{NH}_3(g) \) is reduced to 24.64 mm Hg while the pressures of \( \text{N}_2(g) \) and \( \text{H}_2(g) \) remain at 1 atm.

\[
Q = \frac{P_{\text{NH}_3}^2}{P_{\text{N}_2}P_{\text{H}_2}^3} = \frac{(0.0324)^2}{1(1)^3} = 0.00105
\]

\[
\Delta G^\circ_{\text{Rxn}} = 2\Delta G^\circ_{\text{fNH}_3(g)} - \Delta G^\circ_{\text{fN}_2(g)} - 3\Delta G^\circ_{\text{fH}_2(g)}
\]
\[
\Delta G^\circ_{\text{Rxn}} = 2(-16.5) - 0 - 0 = -33\text{kJ}
\]

\[
\Delta G = -50 \text{kJ}
\]