Chem. 1A Final

Name________________________________________

Student Number _______________________________

All work must be shown on the exam for partial credit. Points will be taken off for incorrect or no units and for the incorrect number of significant figures. A non graphing calculator is allowed. On short answer problems you must show your work in order to receive credit for the problem. If your cell phone goes off during the exam you will have your exam removed from you.

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Fundamental Questions

Each of these fundamental chemistry questions is worth 4 points. **You must show work to get credit.** Little to no partial credit will be rewarded. Make sure to report answers in the correct number of significant figures and with the proper units.

1) **4 pts** What is the equilibrium expression for the following reaction?
   \[ 2\text{HCl(g) + I}_2(\text{s}) \rightarrow 2\text{HI(g) + Cl}_2(\text{g}) \]
   \[ K = \frac{[\text{HI}]^2[\text{Cl}_2]}{[\text{HCl}]^2} \]

2) **4 pts** What is the conjugate base of \( \text{H}_3\text{PO}_4 \)?
   What is the conjugate acid of KOH?
   \( \text{H}_2\text{PO}_4^- \)
   \( \text{H}_3\text{O}^+ \)

3) **4 pts** What is the formula of magnesium bromide?
   What is the name of \( \text{N}_2\text{O}_3 \)?
   \( \text{MgBr}_2 \)
   dinitrogen trioxide

4) **4 pts** Write a balanced chemical reaction for the following process.
   Potassium reacts with water to give potassium hydroxide and hydrogen.
   \[ 2\text{K(s) + 2H}_2\text{O(l) } \rightarrow 2\text{KOH(aq) + H}_2(\text{g}) \]

5) **4 pts** How many protons, neutrons, and electrons in \( ^{59}\text{Fe} \) and \( ^{64}\text{Cu}^- \)?
   \( ^{59}\text{Fe} \):
   \( p = 26, \ e^- = 26, \text{ and } n = 33 \)
   \( ^{64}\text{Cu}^- \):
   \( p = 29, \ e^- = 30, \text{ and } n = 35 \)

6) **4 pts** Calculate the pH of 0.25 M Ba(OH)\(_2\).
   Ba(OH)\(_2\) is a strong base [Ba(OH)\(_2\)]=2[OH\(^-\)]
   \[ 2\text{NaOH(aq) + H}_2\text{SO}_4(\text{aq}) \rightarrow \text{Na}_2\text{SO}_4(\text{aq}) + 2\text{H}_2\text{O} \]
   \[ [\text{OH}^-] = 2(0.25\text{M}) = 0.50\text{M} \]
   \[ p\text{OH} = -\log[\text{OH}^-] = -\log(0.50\text{M}) = 0.30 \]
   \[ p\text{H} = 14.00 - p\text{OH} = 14.00 - 0.30 = 13.70 \]

7) **4 pts** What is the molar solubility of Mg(OH)\(_2\)? \( K_{sp} = 2.06\times10^{-13} \)
   \[ K_{sp} = [\text{Mg}^{2+}][\text{OH}^-]^2 \]
   \[ [\text{Mg}^{2+}] = S \]
   \[ [\text{OH}^-] = 2S \]
   \[ K_{sp} = S[2S]^2 = 4S^3 \]
   \[ S = \sqrt[3]{\frac{K_{sp}}{4}} = \sqrt[3]{\frac{2.06\times10^{-13}}{4}} = 3.72\times10^{-5} \text{mol/L} \]
8) 4 pts On the following periodic table indicate the location of the metals, nonmetals, metalloids. Also label which group is the noble gases, alkaline earth metals, alkali metals, halides, and transition metals.

9) 4 pts How many widgets are in $2.3 \times 10^{-20}$ moles?

$$2.3 \times 10^{-20} \text{ mol} \left( \frac{6.022 \times 10^{23} \text{ widgets}}{1 \text{ mol}} \right) = 1.4 \times 10^4 \text{ widgets}$$

10) 4 pts If the equilibrium constant $K$ for the reaction $A(aq) \rightleftharpoons B(aq)$ is 22 at a given temperature, and if $[A] = 0.10$ M and $[B] = 2.0$ M in a reaction mixture at that temperature, is the reaction at chemical equilibrium? If not, in which direction will the reaction proceed to reach equilibrium?

$$Q = \frac{[B]}{[A]} = \frac{2.0}{0.10} = 20$$

$$Q < K$$

Therefore there are too many reactants and the reaction will proceed to the products (right).

11) 4 pts Calculate the pH of a solution that is 0.60 M HF and 1.00 M KF

$$pH = pK_a + \log \left( \frac{[A]}{[HA]} \right)$$

$$pK_a = -\log K_a = -\log \left( \frac{[A]}{[HA]} \right) = 3.14$$

$$pH = 3.14 + \log \left( \frac{1.00}{0.60} \right) = 3.36$$

12) 4 pts If 10.0 mL of 2.5 M SrCl$_2$ is diluted to 500. mL what is the final concentration of Cl$^-$ ions?

$$M \cdot V_1 = M \cdot V_2$$

$$(2.5 M)(10.0mL) = M(500mL)$$

$$M = \frac{0.050 M \text{ SrCl}_2}{1L \text{ SrCl}_2} \left( \frac{2 \text{ mol} \text{Cl}^-}{1 \text{ mol} \text{SrCl}_2} \right) = 0.10 M \text{ Cl}^-$$
Short Answer Questions
Each of the following short answer questions are worth the noted points. Partial credit will be given. Make sure to show work, report answers to the correct number of significant figures and use the proper units.

1a) 12 pts  The equilibrium constant $K$ for the reaction

$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$$

is 54.3 at 430°C. At the start of the reaction there are 0.713 mole of $H_2$, 0.984 mole of $I_2$, and 0.886 mole of HI in a 2.40 L reaction chamber. Calculate the concentrations of the gases at equilibrium.

<table>
<thead>
<tr>
<th></th>
<th>$H_2$</th>
<th>$I_2$</th>
<th>HI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial (mol)</td>
<td>0.713</td>
<td>0.984</td>
<td>0.886</td>
</tr>
<tr>
<td>Initial (M)</td>
<td>0.297</td>
<td>0.410</td>
<td>0.369</td>
</tr>
</tbody>
</table>

Determine which way the reaction will proceed

$$Q = \frac{[HI]^2}{[H_2][I_2]} = \frac{0.369^2}{(0.297)(0.410)} = 1.12$$

Since $Q<K$ the reaction will proceed toward the products

<table>
<thead>
<tr>
<th></th>
<th>$H_2$</th>
<th>$I_2$</th>
<th>HI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial (M)</td>
<td>0.297</td>
<td>0.410</td>
<td>0.369</td>
</tr>
<tr>
<td>Change</td>
<td>-x</td>
<td>-x</td>
<td>+2x</td>
</tr>
<tr>
<td>Equilibrium</td>
<td>0.297-x</td>
<td>0.410-x</td>
<td>0.369+2x</td>
</tr>
</tbody>
</table>

$$K = \frac{[HI]^2}{[H_2][I_2]} = \frac{(0.369+2x)^2}{(0.297-x)(0.410-x)} = 54.3$$

$$4x^2 + 1.48x + 0.136 = 54.3(x^2 - 0.707x + 0.122)$$

$$4x^2 + 1.43x + 0.136 = 54.3x^2 - 38.4x + 6.62$$

$$50.3x^2 - 39.8x + 6.48 = 0$$

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} = \frac{39.8 \pm \sqrt{-39.8^2 - 4(50.3)(6.48)}}{2(50.3)}$$

$$x = 0.562 \text{ or } 0.229$$

$$x = 0.229 \text{ M because concentration must be positive}$$

$$[H_2] = 0.297 - x = 0.297 - 0.229 = 0.068M$$

$$[I_2] = 0.410 - x = 0.410 - 0.229 = 0.181M$$

$$[HI] = 0.369 + 2x = 0.369 + 2(0.229) = 0.827M$$

1b) 10 pts  When the equilibrium is disturbed, in which direction will the reaction proceed? Circle the correct answer.

$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g) \text{ exothermic}$$

- Remove HI: Reactants, Products: No Change
- Reduce the volume: Reactants, Products: No Change
- Increase the temperature: Reactants, Products: No Change
- Add Ne: Reactants, Products: No Change
- Add $H_2$: Reactants, Products: No Change
A 20.0 L stainless steel container was charged with 2.00 atm of hydrogen gas and 3.0 atm of oxygen gas. A spark ignites the mixture, producing H₂O. What is the pressure in the tank at 25°C?

\[2 \text{H}_2(g) + \text{O}_2(g) \rightarrow 2 \text{H}_2\text{O}(l)\]

What was given

- \(V = 2.00 \text{L}\)
- \(P_{\text{H}_2} = 2.00 \text{atm}\)
- \(P_{\text{O}_2} = 3.00 \text{atm}\)

This is a limiting reagent problem.

Find an expression for the number of moles of \(\text{H}_2\)

\[PV = nRT\]

\[n_{\text{H}_2} = \frac{P_{\text{H}_2}V}{RT} = \frac{(2.00 \text{atm})V}{RT}\]

Find an expression for the number of moles of \(\text{O}_2\)

\[PV = nRT\]

\[n_{\text{O}_2} = \frac{P_{\text{O}_2}V}{RT} = \frac{(3.00 \text{atm})V}{RT}\]

Find the number of moles of \(\text{O}_2\) needed to fully react \(\frac{(2.00 \text{atm})V}{RT}\) moles of \(\text{H}_2\)

\[\frac{(2.00 \text{atm})V}{RT} \text{ mol H}_2 \left( \frac{1 \text{ mol O}_2}{2 \text{ mol H}_2} \right) = \frac{(1.00 \text{ atm})V}{RT} \text{ mol O}_2\]

Since we have \(\frac{(3.00 \text{ atm})V}{RT}\) moles of \(\text{O}_2\), \(\text{H}_2\) is the limiting reagent.

Calculate the moles of \(\text{O}_2\) used (calculated above)

\[\frac{(1.00 \text{ atm})V}{RT} \text{ mol O}_2\]

Calculate the moles of \(\text{O}_2\) left over

\[\frac{(3.00 \text{ atm})V}{RT} - \frac{(1.00 \text{ atm})V}{RT} = \frac{(2.00 \text{ atm})V}{RT}\]

Calculate the total moles present at the end of the reaction

\[n_{\text{tot}} = n_{\text{O}_2} = \frac{(2.00 \text{ atm})V}{RT}\]

Calculate the final pressure

\[PV = nRT\]

\[P = \frac{n_{\text{tot}}RT}{V} = \frac{(\frac{2.00 \text{ atm}}{RT})RT}{V} = 2.00 \text{ atm}\]
3) **14 pts** A 43.29 mL sample of solution containing Fe$^{2+}$ ions is titrated with a 0.0239 M KMnO$_4$ solution. It required 20.97 mL of KMnO$_4$ solution to oxidize all of the Fe$^{2+}$ ions to Fe$^{3+}$ by the following reaction.

\[
\text{MnO}_4^-(aq) + \text{Fe}^{2+}(aq) \xrightarrow{\text{acidic}} \text{Mn}^{2+}(aq) + \text{Fe}^{3+}(aq) \quad \text{(unbalanced)}
\]

What was the concentration of Fe$^{2+}$ ions in the sample solution?

\[
\text{MnO}_4^-(aq) + \text{Fe}^{2+}(aq) \rightarrow \text{Mn}^{2+}(aq) + \text{Fe}^{3+}(aq)
\]

Balance using the \(\frac{1}{2}\) reaction method

- **Reduction** \(\frac{1}{2}\) reaction (Mn $^+$ $\rightarrow$ +2)
  \[
  \text{MnO}_4^-(aq) \rightarrow \text{Mn}^{2+}(aq)
  \]

- **Oxidation** \(\frac{1}{2}\) reaction (Fe $^+$ $\rightarrow$ +3)
  \[
  \text{Fe}^{2+}(aq) \rightarrow \text{Fe}^{3+}(aq) + \text{e}^-
  \]

\[
\text{MnO}_4^-(aq) + 8\text{H}^+(aq) + 5\text{e}^- \rightarrow \text{Mn}^{2+}(aq) + 4\text{H}_2\text{O}(l)
\]

\[
\frac{20.97\text{mL}}{1000\text{mL}} \left(\frac{1\text{L}}{1000\text{mL}}\right) \left(\frac{0.0239\text{molKMnO}_4}{1\text{molKMnO}_4}\right) \left(\frac{1\text{molMnO}_4^-}{1\text{molKMnO}_4}\right) \left(\frac{5\text{molFe}^{2+}}{1\text{molMnO}_4^-}\right) = 0.00251\text{molFe}^{2+}
\]

Calculate the molarity of Fe$^{2+}$

\[
V = 43.29\text{mL} \left(\frac{1\text{L}}{1000\text{mL}}\right) = 0.04329\text{L}
\]

\[
M = \frac{n}{V} = \frac{0.00251\text{mol}}{0.04329\text{L}} = 0.0580M
\]

4) **14 pts** Draw the following titration plots.

a) Strong acid (analyte) Strong base (titrant)

b) Weak acid (analyte) Strong base (titrant)

Make sure to clearly label the equivalence points on both plots.

For plot b also label the region with the maximum buffering, where pH=$pK_a$, the buffer region, where the pH only depends on [HA], and where the pH only depends on [A$^-$].

\[
\begin{array}{cccc}
\text{Volume of Titrant} & 0 & 14 & 0 \\
\text{pH} & 7 & 7 & 0
\end{array}
\]
5) 14 pts  A sample of a compound of Cl and O reacts with an excess of H₂ to give 0.233 g of HCl and 0.403 g of H₂O. Determine the empirical formula of the compound.

\[ \text{Cl}_x \text{O}_y + \text{H}_2 \rightarrow \text{HCl} + \text{H}_2\text{O} \]

Determine the moles of Cl (All of the Cl in \( \text{Cl}_x \text{O}_y \) goes to HCl)

\[
\frac{0.233 \text{ g } \text{HCl}}{36.46 \text{ g } \text{HCl}} \times \frac{1 \text{ mol } \text{Cl}}{1 \text{ mol } \text{HCl}} = 0.00639 \text{ mol } \text{Cl}
\]

Determine the moles of O (All of the O in \( \text{Cl}_x \text{O}_y \) goes to H₂O)

\[
\frac{0.403 \text{ g } \text{H}_2\text{O}}{18.02 \text{ g } \text{H}_2\text{O}} \times \frac{1 \text{ mol } \text{O}}{1 \text{ mol } \text{H}_2\text{O}} = 0.0224 \text{ mol } \text{O}
\]

Divide through by smallest number (0.00881)

Chlorine

\[
\frac{0.00639 \text{ mol}}{0.00881 \text{ mol}} = 1.00
\]

Oxygen

\[
\frac{0.0224 \text{ mol}}{0.00881 \text{ mol}} = 3.51
\]

\( \text{Cl}_3\text{O}_{1.5} \)

Turn to whole number (multiple by 2)

\( \text{Cl}_2\text{O}_7 \)

6a) 12 pts  Determine the acid base properties of the following salts. Circle the correct answer.

<table>
<thead>
<tr>
<th>Salt</th>
<th>Acid</th>
<th>Base</th>
<th>Neutral</th>
</tr>
</thead>
<tbody>
<tr>
<td>KBr</td>
<td></td>
<td></td>
<td><strong>Neutral</strong></td>
</tr>
<tr>
<td>( \text{Al(NO}_3\text{)}_3 )</td>
<td><strong>Acid</strong></td>
<td>Base</td>
<td>Neutral</td>
</tr>
<tr>
<td>( \text{BaCl}_2 )</td>
<td>Acid</td>
<td>Base</td>
<td>Neutral</td>
</tr>
<tr>
<td>( \text{C}_5\text{H}_5\text{NHF} )</td>
<td>Acid</td>
<td>Base</td>
<td><strong>Neutral</strong></td>
</tr>
</tbody>
</table>

6b) 14 pts  What is the the pH of 0.10 M NaCN?

NaCN is a basic salt

\[ \text{CN}^- \text{(aq)} + \text{H}_2\text{O(l)} \rightarrow \text{HCN(aq)} + \text{OH}^-\text{(aq)} \]

\( \text{HCN} \ K_w = 6.2 \times 10^{-10} \)

\[ K_b = \frac{K_w}{K_a} = \frac{1.0 \times 10^{-14}}{6.2 \times 10^{-10}} = 1.6 \times 10^{-5} = \frac{[\text{HCN}][\text{OH}^-]}{[\text{CN}^-]} \]

<table>
<thead>
<tr>
<th>Initial (M)</th>
<th>CN⁻</th>
<th>HCN</th>
<th>OH⁻</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.10</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Change</td>
<td>-x</td>
<td>+x</td>
<td>+x</td>
</tr>
<tr>
<td>Equilibrium</td>
<td>0.10-x</td>
<td>x</td>
<td>x</td>
</tr>
</tbody>
</table>

\[
\frac{[\text{HCN}][\text{OH}^-]}{[\text{CN}^-]} = \frac{xx}{(0.10-x)} = 1.6 \times 10^{-5}
\]

Assume 0.10-x = 0.10

\[
\frac{xx}{(0.10)} = 1.6 \times 10^{-5}
\]

\[ x = 0.0013 \]

Check assumption

\[
\frac{0.0013}{0.10} \times 100\% = 1.3\% \text{ good}
\]
\[ pOH = -\log[OH^-] = -\log(0.0013) = 2.89 \]
\[ pH = 14.00 - pOH = 14.00 - 2.89 = 11.11 \]

**Multiple Choice Questions**

Each of the following multiple choice questions are worth 4 points.

**Your answers need to be filled in on the Scantron provided.**

Note: Your Scantrons will not be returned to you, therefore, for your records, you may want to mark your answers on this sheet.

On the Scantron you need to fill in your perm number, test version, and name. Failure to do any of these things will result in the **loss of 1 point**. Your perm number is placed and bubbled in under the “ID number”. Do not skip boxes or put in a hyphen. In addition, leave bubbles blank under any unused boxes. The version number (A) is bubbled in under the “test form.”

1. The acids HC\(_2\)H\(_3\)O\(_2\) and HF are both weak, but HF is a stronger acid than HC\(_2\)H\(_3\)O\(_2\). HCl is a strong acid. Order the following according to base strength.
   
   A) C\(_2\)H\(_3\)O\(_2\)^– > F\(^–\) > H\(_2\)O > Cl\(^–\)
   
   B) F\(^–\) > C\(_2\)H\(_3\)O\(_2\)^– > H\(_2\)O > Cl\(^–\)
   
   C) C\(_2\)H\(_3\)O\(_2\)^– > F\(^–\) > Cl\(^–\) > H\(_2\)O
   
   D) Cl\(^–\) > F\(^–\) > C\(_2\)H\(_3\)O\(_2\)^– > H\(_2\)O
   
   E) none of these

2. Consider a solution of 2.0 \(M\) HCN and 1.0 \(M\) NaCN (\(K_a\) for HCN = 6.2 \(\times\) 10\(^{-10}\)). Which of the following statements is true?
   
   A) The pH will be below 7.00 because the concentration of the acid is greater than that of the base.
   
   B) The buffer will be more resistant to pH changes from addition of strong acid than to pH changes from addition of strong base.
   
   C) The solution is not a buffer because [HCN] is not equal to [CN\(^–\)].
   
   D) [OH\(^–\)] > [H\(^+\)]
   
   E) All of these statements are false.

3. In the reaction Zn + H\(_2\)SO\(_4\) \(\rightarrow\) ZnSO\(_4\) + H\(_2\), which element, if any, is oxidized?
   
   A) Sulfur
   
   B) Oxygen
   
   C) Hydrogen
   
   D) Zinc
   
   E) none of these
4. Given:
\[ \text{P}_4(\text{s}) + 6\text{Cl}_2(\text{g}) \rightleftharpoons 4\text{PCl}_3(\text{l}) \]
\[ K \]
Calculate the equilibrium constant for the following reaction.
\[ 2\text{PCl}_3(\text{l}) \rightleftharpoons 3\text{Cl}_2(\text{g}) + \frac{1}{2} \text{P}_4(\text{s}) \]
A) \( 1/K^2 \)
B) \( 1/K \)
C) \( K^{1/2} \)
D) \( -K^{1/2} \)
E) \( 1/K^{1/2} \)

5. A plot of the Maxwell distribution against speed for different molecules shows that
A) light molecules have a very narrow range of speeds.
B) light molecules have a lower average speed.
C) heavy molecules have a higher average speed.
D) heavy molecules travel with speeds close to their average values.
E) heavy molecules have a wide range of speeds.

6. The following Kp values were collected for a system.
\[ \text{K}_{p1} = 6.8 \times 10^{-4} \quad T=25^\circ \text{C} \]
\[ \text{K}_{p2} = 1.9 \times 10^{-4} \quad T=400^\circ \text{C} \]
Is the reaction endothermic or exothermic?
A) Endothermic
B) Exothermic

7. What is the relationship between \( K \) and \( K_p \) for the reaction below?
\[ 2\text{HgO(s)} \rightleftharpoons 2\text{Hg(l)} + \text{O}_2(\text{g}) \]
A) \( K = RTK_p \)
B) \( K = (RT)^2K_p \)
C) \( K_p = (RT)^2K \)
D) \( K_p = K \)
E) \( K_p = RTK \)

8. Consider the reaction between 50.0 mL of 0.200 \( M \) sodium hydroxide and 75.0 mL of 0.100 \( M \) HCl. Which of the following statements is correct?
A) The NaOH is the limiting reactant.
B) After the reaction, the concentration of Na\(^+\) is equal to the concentration of Cl\(^-\).
C) After the reaction, the concentration of Na\(^+\) is still 0.200 \( M \) because Na\(^+\) is a spectator ion.
D) After the reaction, the concentration of Na\(^+\) is greater than the concentration of OH\(^-\).
E) None of these are correct.
9. High concentrations of aqueous solutions of potassium sulfide and nickel(II) nitrate are mixed together. Which statement is correct?
   A) No precipitate forms.
   B) NiS will precipitate from solution.
   C) No reaction will occur.
   D) Both KNO₃ and NiS precipitate from solution.
   E) KNO₃ will precipitate from solution.

10. Which of the following statements concerning equilibrium is not true?
   A) The equilibrium constant is independent of temperature.
   B) The value of the equilibrium constant for a given reaction mixture is the same regardless of the direction from which equilibrium is attained.
   C) A system that is disturbed from an equilibrium condition responds in such a way as to restore equilibrium.
   D) Equilibrium in molecular systems is dynamic, with two opposing processes balancing one another.
   E) A system moves spontaneously toward a state of equilibrium.

11. Which of the following is not the correct chemical formula for the compound named?
   A) Zn₃P₂ zinc phosphide
   B) HCl hydrogen chloride
   C) CaBr₂ calcium bromide
   D) LiOH lithium hydroxide
   E) Fe₂SO₄ iron(II) sulfate

12. Consider the following statements:
   1. Real gases act more like ideal gases as the temperature increases.
   2. When n and T are constant, a decrease in P results in a decrease in V.
   3. At 1 atm and 273 K, every molecule in a sample of a gas has the same speed.
   4. At constant T, CO₂ molecules at 1 atm and H₂ molecules at 5 atm have the same average kinetic energy.
   Which of these statements is true?
   A) 1 and 2
   B) 2 and 4
   C) 3 and 4
   D) 2 and 3
   E) 1 and 4
Answer Key

1. A
2. D
3. D
4. E
5. D
6. B
7. E
8. D
9. B
10. A
11. E
12. E