Exam 2

DO NOT OPEN THE EXAM UNTIL INSTRUCTED

Directions

Please check the exam to make sure there are 13 non-blank pages including the title page. Pages 11, 12 and 13 contain data tables and a periodic chart which you may remove and use as scratch paper. Read all the questions and directions carefully before entering answers!

SECTION I: MULTIPLE CHOICE – You must insert your UWSP student ID number (all eight digits) and blacken the appropriate bubbles with a #2 pencil. Insert your name and blacken the bubbles. DO NOT MAKE ANY STRAY MARKS ON THE FORM OR ERRORS WILL OCCUR.

Sections III - V allow you to omit a problem. Please read the directions for each section write “OMIT” on the portion you do not want graded. If nothing is marked “OMIT” we will grade the first problems of that section, regardless of what work has been done. We will not attempt to interpret your desire.

When you have completed the exam please place the exam neatly on the front bench.

Pencils and pens down when time is called.

Good Luck!
I. Multiple Choice (30 pts) *Please carefully blacken the bubble on the scantron sheet for the answer you have selected for the following multiple choice questions.*

1. What color is your exam?
   a. yellow
   b. blue
   c. green

2. Which one of the following compounds produces 4 ions per formula unit by dissociation when dissolved in water?
   A) \( \text{Hg}_2\text{Cl}_2 \)
   B) \( \text{Li}_3\text{PO}_4 \)
   C) \( (\text{NH}_4)_2\text{SO}_4 \)
   D) \( (\text{NH}_4)_4\text{Fe(CN)}_6 \)
   E) \( \text{Ca(NO}_3)_2 \)

3. Which one of the following compounds is soluble in water?
   A) \( \text{CaCO}_3 \)
   B) \( \text{PbCO}_3 \)
   C) \( \text{MgCl}_2 \)
   D) \( \text{BaSO}_4 \)
   E) \( \text{AgBr} \)

4. Which one of the statements below is true concerning an oxidation-reduction reaction?
   A) the reactant which gains electrons is the reducing reagent
   B) none of the statements, a—d, is true for an oxidation-reduction reaction
   C) the reactant which loses electrons is the oxidizing reagent
   D) the reactant which is being oxidized is the reducing reagent
   E) the reactant which is being reduced is the reducing reagent

5. Which one of the following would not be acidic?
   A) *household ammonia*
   B) carbonated water
   C) vinegar
   D) lemon juice
   E) grapefruit juice

6. A solution is made by taking 54.62 grams of \( \text{K}_2\text{CrO}_4 \) (194.19 g/mol) in enough water to make 250.0 mL of solution. The molarity of the solution is therefore
   A) 0.2813 molar
   B) 0.0002813 molar
   C) 1.409 molar
   D) 0.001125 molar
   E) 1.125 molar
7. A sample of sulfolane, C₄H₈O₂S, contains 5.00 x 10²⁴ total atoms. How many moles of sulfolane are there in the sample? (Avogadro’s number: 6.022 x 10²³)
   A) 0.554 moles
   B) 3.33 x 10²³ moles
   C) 0.120 moles
   D) 1.81 moles
   E) 8.30 moles

8. Which one of the following processes represents a reduction?
   A) CrO₂⁻(aq) → CrO₄²⁻(aq)
   B) 2 S₂O₇²⁻(aq) + H₂O(l) → 2 SO₄²⁻(aq) + 2 H⁺(aq)
   C) 2 H⁺(aq) + SO₃²⁻(aq) → H₂O(l) + SO₂(g)
   D) VO₄³⁻(aq) → VO²⁺(aq)
   E) Ca²⁺(aq) + CO₃²⁻(aq) → CaCO₃(s)

9. What is the percent, by weight, of oxygen in NiSO₄·7H₂O?
   A) 62.661
   B) 49.531
   C) 39.875
   D) 14.846
   E) 43.273

10. What is the formula weight of (NH₄)₂SO₄?
    A) 84.14
    B) 114.10
    C) 132.14
    D) 116.07
    E) None of these

11. What is the oxidation number of the nitrogen atoms in (NH₄)₂SO₄?
    A) +2
    B) +1
    C) +3
    D) -2
    E) -3
II. Nomenclature (10 pts)

A. (5) Provide chemical formulas for the following:

(1) Nitrous Acid   \( \text{HNO}_2 \) .................................................................

(1) Calcium hydroxide   \( \text{Ca(OH)}_2 \) .................................................................

(1) Hydroiodic acid   \( \text{HI} \) .................................................................

(1) Ammonia   \( \text{NH}_3 \) (or \( \text{NH}_2\text{OH} \), but it was not specified aqueous) .................................................................

(1) Hydrochloric acid   \( \text{HCl} \) .................................................................

B. (5) Provide names for the following:

(1) \( \text{H}_2\text{SO}_4\text{(aq)} \)   Sulfuric acid .................................................................

(1) \( \text{HNO}_2\text{(aq)} \)   Nitrous acid .................................................................

(1) \( \text{HNO}_3\text{(aq)} \)   Nitric acid .................................................................

(1) \( \text{Mg(OH)}_2\text{(aq)} \)   Magnesium hydroxide .................................................................

(1) \( \text{MnO(s)} \)   Manganese (II) oxide .................................................................
III. Fill in the Blank (15 pts) Solve any three (3) of the following problems and place your answer in the boxes provided. Note that very little partial credit will be given, so check your answers carefully.

1. How many grams of sodium carbonate are needed to make 75.00 100.00 150.00 mL of a 0.010M solution? (1 Mole Na₂CO₃ =105.99 g)

\[
\frac{0.010 \text{ mol Na}_2\text{CO}_3 \times 0.075 \text{ L Na}_2\text{CO}_3}{1 \text{ mol Na}_2\text{CO}_3} = 0.0794925 \text{ g Na}_2\text{CO}_3
\]

Yellow: 0.079 g Na₂CO₃
Blue: 0.11 g Na₂CO₃
Green: 0.16 g Na₂CO₃

2. Given the balanced reaction

\[4 \text{ NH}_3 + 5 \text{ O}_2 \rightarrow 4 \text{ NO} + 6 \text{ H}_2\text{O}\]

How many grams of ammonia would you require if you had unlimited oxygen and desired to make 156 256 356 g of nitrogen monoxide by this method? (NO is 30.006g/mole and NH₃ is 17.0305g/mole)

\[
\frac{156 \text{ g NO} \times 1 \text{ mol NO} \times 4 \text{ mol NH}_3}{30.006 \text{ g NO} \times 4 \text{ Mol NO} \times 1 \text{ mol NH}_3} = 88.5408 \text{ g NH}_3
\]

Yellow: 88.5 g NH₃
Blue: 145 g NH₃
Green: 202 g NH₃

3. If 35.06 235.1 535.6 mL of 3.35 M HNO₃ is diluted to 2.000L, what is the resulting concentration?

\[m_1 \times v_1 = m_2 \times v_2\]
\[m_2 \times v_2 = \frac{m_1 \times v_1}{v_2} = \frac{3.35 \text{ M} \times 35.06 \text{ mL}}{2000 \text{ mL}} = 0.0587255 \text{ M}\]

Yellow: 0.0587M
Green: 0.395M
Blue: 0.897M

4. Tin (II) ions react with iron (III) ions. The tin gets oxidized to Sn⁴⁺ while the iron gets reduced to Fe²⁺. Write a balanced reaction for this redox reaction.

\[\text{Sn}^{2+} \rightarrow \text{Sn}^{4+} + 2e^-\]
\[2e^- + 2\text{Fe}^{3+} \rightarrow 2 \text{Fe}^{2+}\]
\[\text{Sn}^{2+} + 2\text{Fe}^{3+} \rightarrow \text{Sn}^{4+} + 2 \text{Fe}^{2+}\]

\[\text{Sn}^{2+} + 2\text{Fe}^{3+} \rightarrow \text{Sn}^{4+} + 2 \text{Fe}^{2+}\]
IV. Definition and short explanation (10) Answer two of the four following questions using complete sentences. You must write OMIT in the question that you choose to not answer.

1. Weak acid
Weak acid is a chemical substance that produces H+ or H3O+ in solution but it does not dissociate 100%.

2. Acid anhydride
Acid anhydride is a non-metal oxide that produces H3O+ when mixed with water.

3. Net ionic equation
A net ionic equation is a representation of a reaction containing just the ions that participate to form a substantially changed product. There are no spectator ions in a net ionic equation.

4. Percent yield
Percent yield is the amount of material actual obtained in a reaction divided by the amount that was theoretically possible, times 100%.
V. Problems (15) Solve/answer all of the following questions. Show your work, including units, to receive full credit.

1. Assign oxidation numbers to each element in the following species:

\[ \text{CsBrO}_{234}(aq) \]

Yellow: Cs \(_{+1}\) Br \(_{+3}\) O \(_{-2}\)  
Blue: Cs \(_{+1}\) Br \(_{+7}\) O \(_{-2}\)  
Green: Cs \(_{+1}\) Br \(_{+5}\) O \(_{-2}\) 

\[ \text{H}_3\text{PO}_{234}(aq) \]

Yellow: H \(_{+1}\) P \(_{+1}\) O \(_{-2}\)  
Blue: H \(_{+1}\) P \(_{+5}\) O \(_{-2}\)  
Green: H \(_{+1}\) P \(_{+3}\) O \(_{-2}\) 

2. Circle the compounds below that are soluble insoluble soluble in water: (shown here in bold rather than circled)

- KCl
- BaSO\(_4\)
- Ca(OH)\(_2\)
- Zn(ClO\(_4\))\(_2\)
- NiCO\(_3\)

- KCl
- BaSO\(_4\)
- Ca(OH)\(_2\)
- Zn(ClO\(_4\))\(_2\)
- NiCO\(_3\)

- LiBr
- ZnSO\(_3\)
- Ba(OH)\(_2\)
- Ni(ClO\(_4\))\(_2\)
- MnCO\(_3\)

3. Using the relative reactivity table on page 12 of this exam predict whether a reaction will occur for the following. Write a balanced chemical reaction or NO REACTION in the space provided.

- \( \text{Cu} + \text{HCl} \rightarrow \text{no reaction} \)

- \( \text{Cu} + 2\text{AgNO}_3(aq) \rightarrow \text{Cu(NO}_3)_2 + 2\text{Ag} \)

- \( \text{Au} + \text{AgNO}_3(aq) \rightarrow \text{no reaction} \)
VI. Thought Questions (20 pts) Answer the questions on any two (2) of the following three pages. Write "OMIT" through the page you wish omitted. Your answers must be clear and complete in order to receive complete credit. SHOW YOUR WORK!

1. Balance the following redox reactions in aqueous media under the specified conditions:

**Acidic conditions:** \( \text{S}_2\text{O}_3^{2-} + \text{OCl}^- \rightarrow \text{Cl}^- + \text{S}_4\text{O}_6^{2-} \)

\[
2e^- + 2\text{H}^+ + \text{OCl}^- \rightarrow \text{Cl}^- + \text{H}_2\text{O} \\
2\text{S}_2\text{O}_3^{2-} \rightarrow \text{S}_4\text{O}_6^{2-} + 2e^-
\]

**Acidic conditions:** \( \Gamma + \text{HSO}_4^- \rightarrow \text{I}_2 + \text{SO}_2 \)

\[
2\Gamma \rightarrow \text{I}_2 + 2e^- \\
2e^- + 3\text{H}^+ + \text{HSO}_4^- \rightarrow \text{SO}_2 + 2\text{H}_2\text{O}
\]

**Acidic conditions:** \( \text{I}_2 + \text{OCl}^- \rightarrow \text{IO}_3^- + \text{Cl}^- \)

\[
6\text{H}_2\text{O} + \text{I}_2 \rightarrow 2\text{IO}_3^- + 12\text{H}^+ + 10e^- \\
10e^- + 10\text{H}^+ + 5\text{OCl}^- \rightarrow 5\text{Cl}^- + 5\text{H}_2\text{O}
\]

\[
5\text{OCl}^- \text{H}_2\text{O} + \text{I}_2 \rightarrow 2\text{IO}_3^- + 2\text{H}^+ + 5\text{Cl}^-
\]

**Basic conditions:** \( \text{ClO}_3^- + \text{N}_2\text{H}_4 \rightarrow \text{NO} + \text{Cl}^- \)

\[
24e^- + 24\text{H}^+ + 4\text{ClO}_3^- \rightarrow 4\text{Cl}^- + 12\text{H}_2\text{O} \\
6\text{H}_2\text{O} + 3\text{N}_2\text{H}_4 \rightarrow 6\text{NO} + 24\text{H}^+ + 24e^-
\]

This is the same in acidic or basic since there are no \( \text{H}^+ \)

\[
4\text{ClO}_3^- + 3\text{N}_2\text{H}_4 \rightarrow 4\text{Cl}^- + 6\text{H}_2\text{O} + 6\text{NO}
\]

**Basic conditions:** \( \text{MnO}_4^- + \text{C}_2\text{O}_4^{2-} \rightarrow \text{CO}_2 + \text{MnO}_2 \)

\[
6e^- + 8\text{H}^+ + 2\text{MnO}_4^- \rightarrow 2\text{MnO}_2 + 4\text{H}_2\text{O} \\
3\text{C}_2\text{O}_4^{2-} \rightarrow 6\text{CO}_2 + 6e^-
\]

In **acid** \( 6e^- + 8\text{H}^+ + 2\text{MnO}_4^- + 3\text{C}_2\text{O}_4^{2-} \rightarrow 2\text{MnO}_2 + 4\text{H}_2\text{O} + 6\text{CO}_2 + 6e^- \)

In **base** \( 8\text{OH}^- + 8\text{H}^+ + 2\text{MnO}_4^- + 3\text{C}_2\text{O}_4^{2-} \rightarrow 2\text{MnO}_2 + 4\text{H}_2\text{O} + 6\text{CO}_2 + 8\text{OH}^- \)

\[
4\text{H}_2\text{O} + 2\text{MnO}_4^- + 3\text{C}_2\text{O}_4^{2-} \rightarrow 2\text{MnO}_2 + 6\text{CO}_2 + 8\text{OH}^-
\]

**Basic conditions:** \( \text{SO}_3^{2-} + \text{MnO}_4^- \rightarrow \text{SO}_4^{2-} + \text{MnO}_2 \)

\[
6e^- + 8\text{H}^+ + 2\text{MnO}_4^- \rightarrow + + 2\text{MnO}_2 + 4\text{H}_2\text{O} \\
3\text{H}_2\text{O} + 3\text{SO}_3^{2-} \rightarrow 3\text{SO}_4^{2-} + 6\text{H}^+ + 6e^-
\]

In **acid** \( 6e^- + 28\text{H}^+ + 2\text{MnO}_4^- + 3\text{H}_2\text{O} + 3\text{SO}_3^{2-} \rightarrow 2\text{MnO}_2 + 14\text{H}_2\text{O} + 3\text{SO}_4^{2-} + 6\text{H}^+ + 6e^- \)

In **base** \( [2\text{OH}^- + 2\text{H}^-] + 2\text{MnO}_4^- + 3\text{SO}_3^{2-} \rightarrow 2\text{MnO}_2 + \text{H}_2\text{O} + 3\text{SO}_4^{2-} + 2\text{OH}^- \)

\[
\text{H}_2\text{O} + 2\text{MnO}_4^- + 3\text{SO}_3^{2-} \rightarrow 2\text{MnO}_2 + 3\text{SO}_4^{2-} + 2\text{OH}^-
\]
2. You must show all of your calculations with complete labels to receive full credit on these questions. The primary standard potassium hydrogen phthalate, KHC₈H₄O₄, (204.2 g/mole) weighing 0.403 g was titrated to a pink phenolphthalein endpoint that required 43.19 mL 33.19 mL 23.19 mL of barium hydroxide solution. The following balanced reaction occurred.

\[ \text{Ba(OH)}_2 (\text{aq}) + 2 \text{KHC}_8\text{H}_4\text{O}_4 (\text{aq}) \rightarrow 2 \text{H}_2\text{O}(\text{l}) + \text{Ba(KC}_8\text{H}_4\text{O}_4)_2 (\text{aq}) \]

What is the molarity of the barium hydroxide solution?

Yellow:
\[
\frac{0.403 \text{ g KHP}}{204.2 \text{ g KHP}} \cdot \frac{1 \text{ mol KHP}}{1 \text{ mol Ba(OH)}_2} \cdot \frac{1 \text{ mol Ba(OH)}_2}{2 \text{ mol KHP}} \cdot \frac{0.04319 \text{ L Ba(OH)}_2}{0.0228 \text{ mol Ba(OH)}_2} = \frac{0.0297 \text{ mol Ba(OH)}_2}{\text{L Ba(OH)}_2}
\]

Green:
\[
\frac{0.403 \text{ g KHP}}{204.2 \text{ g KHP}} \cdot \frac{1 \text{ mol KHP}}{1 \text{ mol Ba(OH)}_2} \cdot \frac{1 \text{ mol Ba(OH)}_2}{2 \text{ mol KHP}} \cdot \frac{0.04319 \text{ L Ba(OH)}_2}{0.0426 \text{ mol Ba(OH)}_2} = \frac{0.0297 \text{ mol Ba(OH)}_2}{\text{L Ba(OH)}_2}
\]

Blue:
\[
\frac{0.403 \text{ g KHP}}{204.2 \text{ g KHP}} \cdot \frac{1 \text{ mol KHP}}{1 \text{ mol Ba(OH)}_2} \cdot \frac{1 \text{ mol Ba(OH)}_2}{2 \text{ mol KHP}} \cdot \frac{0.04319 \text{ L Ba(OH)}_2}{0.0426 \text{ mol Ba(OH)}_2} = \frac{0.0297 \text{ mol Ba(OH)}_2}{\text{L Ba(OH)}_2}
\]
3. An unknown compound was found to consist of the elements carbon, hydrogen, nitrogen and oxygen. Elemental analysis gave: C, 39.14%; H, 2.19% and N, 15.22%. What is the empirical formula of this compound?

Assume 100 g sample divide by 1.087 (smallest # of moles) multiply by 2 to get rid of 2.5

\[
\begin{align*}
\frac{39.14 \text{ g C}}{12 \text{ g C}} &= 3.26 \text{ mol C} = 3 \Rightarrow 6 \\
\frac{2.19 \text{ g H}}{1 \text{ g H}} &= 2.19 \text{ mol H} = 2 \Rightarrow 4 \\
\frac{15.22 \text{ g H}}{14 \text{ g N}} &= 1.087 \text{ mol N} = 1 \Rightarrow 2 \\
\frac{43.45 \text{ g O}}{16 \text{ g O}} &= 2.715 \text{ mol O} = 2.49 \Rightarrow 5
\end{align*}
\]

If everything totals 100%, then O must be 43.45%

Therefore the empirical formula is \( \text{C}_6\text{H}_4\text{N}_2\text{O}_5 \)

Molecular formula was not graded full points were awarded for getting the answer above.
Solubility rules for ionic compounds in water:

Soluble Compounds
1) All compounds of the alkali metals (Group IA)
2) All salts containing NH$_4^+$, NO$_3^-$, ClO$_4^-$, ClO$_3^-$, and C$_2$H$_3$O$_2^-$
3) All chlorides, bromides, and iodides (salts containing Cl$^-$, Br$^-$, or I$^-$)  
   except when combined with Ag$^+$, Pb$^{2+}$, and Hg$_2^{2+}$
4) All sulfates (salts containing SO$_4^{2-}$)
   except those of Pb$^{2+}$, Ca$^{2+}$, Sr$^{2+}$, Hg$_2^{2+}$, and Ba$^{2+}$

Insoluble compounds
5) All metal hydroxides (ionic compounds containing OH$^-$) and all metal oxides (ionic compounds containing O$^{2-}$) are insoluble
   except those of Group IA and of Ca$^{2+}$, Sr$^{2+}$, and Ba$^{2+}$

When metal oxides dissolve, they react with water to form hydroxides. The oxide ion, O$^-$, does not exist in water. For example, Na$_2$O(s) + H$_2$O(l) $\rightarrow$ 2NaOH(aq)
6) All salts that contain PO$_4^{3-}$, CO$_3^{2-}$, SO$_3^{2-}$, and S$^{2-}$ are insoluble,
   except those of Group IA and NH$_4^+$.

A knowledge of these rules will allow you to predict a large number of precipitation reactions

**Oxidation numbers** provide a way to keep track of electron transfers:

1. The oxidation number of any free element is zero.
2. The oxidation number of any simple, monoatomic ion is equal to the charge on the ion.
3. The sum of all oxidation numbers of the atoms in a molecule or polyatomic ion must equal the charge on the particle.
4. In its compounds, fluorine has an oxidation number of $-1$.
5. In its compounds, hydrogen has an oxidation number of $+1$.
6. In its compounds, oxygen has an oxidation number of $-2$.

If there is a conflict between two rules apply the rule with the lower number and ignore the conflicting rule.

In binary ionic compounds with metals, the nonmetals have oxidation numbers equal to the charges on their anions
Balancing Oxidation-Reduction reactions – Ion-Electron Method

Many reactions occur in either acidic or basic solutions

The Ion-Electron Method in Acidic Solution:

1. Divide the equation into two half-reactions.
2. Balance atoms other than H and O.
3. Balance O by adding water.
4. Balance H by adding hydrogen ion.
5. Balance net charge by adding electrons.
6. Make electron gain and loss equal: add half-reactions.
7. Cancel anything that’s the same on both sides of the equation.

The simplest way to balance reactions in basic solution is to first balance them as if they were in acidic solution, then “convert” to basic solution:

**Additional Steps for Basic Solutions**

8. Add the same number of OH\(^-\) ions as H\(^+\) to both sides
9. Combine H\(^+\) and OH\(^-\) ions to form H\(_2\)O.
10. Cancel any H\(_2\)O that you can.

**Relative Reactivity Series**

<table>
<thead>
<tr>
<th>Element</th>
<th>Oxidation Product</th>
</tr>
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<tbody>
<tr>
<td>Least Active</td>
<td></td>
</tr>
<tr>
<td>Gold</td>
<td>Au(^{3+})</td>
</tr>
<tr>
<td>Mercury</td>
<td>Hg(^{2+})</td>
</tr>
<tr>
<td>Silver</td>
<td>Ag(^+)</td>
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<tr>
<td>Copper</td>
<td>Cu(^{2+})</td>
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<td>Hydrogen</td>
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