Chem 115 Problem Session #1 Solutions
Chem 112/114 Review and Chem 115 Preparation

All answers must be given with the correct units and number of significant figures. For questions 1-14, use scrap paper for your work and record only your answers in the spaces provided. For question 15 through 18, your work must be shown in detail. Questions will be marked for completeness, however will not be graded. Attach additional pages showing your work.

1. The chemical formula for lithium sulfite is: \( \text{Li}_2\text{SO}_3 \)
2. The name of the \( \text{ClO}_2^- \) ion is: chlorite
3. The oxidation number of C in \( \text{H}_2\text{CO}_2 \) is: +2
4. The number of significant figures in 0.0002470 is: 4
5. When adding the masses 0.056 kg, 145.213 g, and 1635 mg, what is the total mass in grams given to the correct number of significant figures? 203 g
6. The chemical formula for hydroiodic acid is: \( \text{HI}(aq) \)
7. Liquid oxygen boils at 90.2 K. What is its boiling point on the Celsius scale? -183.0 \(^\circ\)C
8. The pressure needed to make synthetic diamonds from graphite is \( 8.0 \times 10^4 \) atm. What is this pressure expressed in Pascals? \( 8.1 \times 10^9 \) Pa
9. 1.00 g of, \( \text{Na}_2\text{Cr}_2\text{O}_7 \), contains how many chromium atoms? \( 4.60 \times 10^{21} \) Cr atoms
10. The mass (in grams) of one molecule of ammonia to two significant figures is: \( 2.8 \times 10^{-23} \) g
11. At 25 \(^\circ\)C, bromine is a liquid and has a density of 3.12 g/mL. What volume is occupied by 100.0 g of bromine? 32.1 mL
12. A gas occupies 1.5 L at 1.0 atm at standard temperature. What will the volume be if both the pressure and temperature are decreased to 80% of its original pressure and temperature? 1.5 L
13. What is the molarity of a solution that contains 85.0 g of HCl in 275 mL of solution? 8.48 M
14. Balance the following equations:
   a. \( \underline{\_} \text{P}_2\text{O}_5 \) (s) + \( \underline{\_} \text{H}_2\text{O} \) (l) \( \rightarrow \) \( \underline{\_} \text{H}_3\text{PO}_4 \) (l)
   b. \( \underline{\_} \text{Pb(NO}_3)_2 \) (aq) + \( \underline{\_} \text{Na}_3\text{PO}_4 \) (aq) \( \rightarrow \) \( \underline{\_} \text{Pb}_3\text{(PO}_4)_2 \) (s) + \( \underline{\_} \text{NaNO}_3 \) (aq)
   c. \( \underline{\_} \text{Ag}^+ \) (aq) + \( \underline{\_} \text{Cu} \) (s) \( \rightarrow \) \( \underline{\_} \text{Ag} \) (s) + \( \underline{\_} \text{Cu}^{2+} \) (aq)
15. Octane ($C_8H_{18}$) is a major component of gasoline. When octane burns in excess oxygen, water is produced as well as carbon dioxide. (For this reason, clouds of condensed water droplets are often seen coming from automobile exhausts, especially on cold days.) The density of gasoline is 0.79 g/mL.

a. Write the balanced chemical equation for the combustion of octane.

$$C_8H_{18} + O_2 \rightarrow CO_2 + H_2O \quad \text{basic equation (1 mark for correct combustion)}$$

$$2C_8H_{18} + 25O_2 \rightarrow 16CO_2 + 18H_2O \quad (1 \text{ mark for correct balancing})$$

b. Calculate the mass of water produced from the combustion of 1.0 L of octane.

1.0 L octane…if we assume gasoline is made purely of octane then…

$$d = \frac{m}{V} \quad m = Vd = (1000 \text{ mL})(0.79 \text{ g/mL}) = 790 \text{ g } C_8H_{18} \quad (1 \text{ mark})$$

$$790 \text{ g } C_8H_{18} \times \frac{1 \text{ mol } C_8H_{18}}{114.232 \text{ g}} \times \frac{18 \text{ mol } H_2O}{2 \text{ mol } C_8H_{18}} \times \frac{18.015 \text{ g } H_2O}{1 \text{ mol } H_2O} = 1.1 \times 10^3 \text{ g } H_2O$$

(I mark for correct stoichiometry and 1 for correct answer)

c. What volume of carbon dioxide (at STP) is produced from the combustion of 1.0 L of octane?

$$790 \text{ g } C_8H_{18} \times \frac{1 \text{ mol } C_8H_{18}}{114.232 \text{ g}} \times \frac{16 \text{ mol } CO_2}{2 \text{ mol } C_8H_{18}} = 55.326 \text{ mol } CO_2 \quad (1 \text{ mark})$$

$$PV=nRT \quad V = \frac{nRT}{P} \times \frac{(55.326 \text{ mol})(0.082096 \text{ Latm/molK})(273.15 \text{ K})}{1 \text{ atm}}$$

$$= 1.2 \times 10^3 \text{ L } CO_2 \quad (1 \text{ for using } PV=nRT, \text{ 1 for correct answer})$$

16. A 15.00 mL sample of Ca(OH)$_2$ (aq) was titrated with 17.40 mL of 0.234 M HCl (aq).

a. Write the balanced chemical equation for the reaction.

$$Ca(OH)_2(aq) + 2HCl(aq) \rightarrow Ca^{2+}(aq) + 2Cl^-(aq) + 2H_2O(l)$$

b. What is the molarity of the Ca(OH)$_2$ (aq) solution?

$$n=MV = (0.234 \text{ M})(0.01740 \text{ L})$$

$$= 0.004072 \text{ mol } HCl \times \frac{1 \text{ mol } Ca(OH)_2}{2 \text{ mol } HCl} = 0.002036 \text{ mol } Ca(OH)_2$$

$$M = \frac{n}{V} = \frac{0.002036 \text{ mol } Ca(OH)_2}{0.01500 \text{ L}} = 0.136 \text{ M } Ca(OH)_2$$
17. The souring of wine occurs when ethanol, \( \text{C}_2\text{H}_5\text{OH} \), is converted by oxidation into acetic acid:

\[
\text{C}_2\text{H}_5\text{OH (aq)} + \text{O}_2 (g) \rightarrow \text{CH}_3\text{COOH (aq)} + \text{H}_2\text{O (l)}
\]

If 100.0 mL of wine (which is 14.2% ethanol by mass) was oxidized by 5.00 g of oxygen, determine the concentration of the resulting acetic acid assuming complete reaction. Assume the density of the wine is 1.00 g/mL, and remember to include the water produced during the oxidation process.

Given: 100.0 mL solution (wine) = 100 g (due to density)

Wine = 14.2 g \( \text{C}_2\text{H}_5\text{OH} \) / 100 g solution (ie. 14.2% by mass)

Therefore: 100 g solution x 14.2 g \( \text{C}_2\text{H}_5\text{OH} \) / 100 g solution = 14.2 g \( \text{C}_2\text{H}_5\text{OH} \)

\[
\begin{align*}
\text{mol CH}_3\text{COOH} &= 0.3082 \\
\text{mol O}_2 &= 0.1563 \\
\text{mol H}_2\text{O} &= 2.816 \\
\text{M CH}_3\text{COOH} &= 1.52
\end{align*}
\]

18. Answer the questions below regarding the following redox reaction.

\[
\text{Mn}^{2+} (aq) + \text{H}_2\text{O}_2 (aq) \rightarrow \text{MnO}_2 (s) + \text{H}_2\text{O (l)} \quad \text{in basic solution}
\]

a. What are the oxidation states of all elements in the redox reaction?
<table>
<thead>
<tr>
<th>Mn$^{2+}$</th>
<th>H$_2$O$_2$</th>
<th>$\rightarrow$</th>
<th>MnO$_2$</th>
<th>H$_2$O</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mn : +2</td>
<td>H : +1</td>
<td>O : -2</td>
<td>Mn : +4</td>
<td>O :-2</td>
</tr>
</tbody>
</table>

b. Which species is the oxidizing agent, and which is the reducing agent?

Mn$^{2+}$ is oxidized to Mn: +4, therefore it is the reducing agent.

O gets reduced from oxidation state -1 to -2 therefore it is the oxidizing agent.

c. Balance the redox reaction in basic solution using the half-reaction method. Show all steps to receive full marks.

Oxidation half-rxn  
$\text{Mn}^{2+} (\text{aq}) \rightarrow \text{MnO}_2 (\text{s})$

Reduction half-rxn  
$\text{H}_2\text{O}_2 (\text{aq}) \rightarrow \text{H}_2\text{O(l)}$

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Balance non-H,O atoms,  
Balance O and H  
$2\text{H}_2\text{O(l)} + \text{Mn}^{2+} (\text{aq}) \rightarrow \text{MnO}_2(\text{s}) + 4\text{H}^+(\text{aq})$

$2\text{H}^+(\text{aq}) + \text{H}_2\text{O}_2 (\text{aq}) \rightarrow 2\text{H}_2\text{O(l)}$

--

Convert H$^+$ to OH$^-$ for Basic solution  
$4\text{OH}^- + 2\text{H}_2\text{O} + \text{Mn}^{2+} \rightarrow \text{MnO}_2 + 4\text{H}^+ + 4\text{OH}^-$

$2\text{OH}^- + 2\text{H}^+ + \text{H}_2\text{O}_2 (\text{aq}) \rightarrow 2\text{H}_2\text{O(l)} + 2\text{OH}^-$

Which simplifies to…  
$4\text{OH}^- + \text{Mn}^{2+} \rightarrow \text{MnO}_2 + 2\text{H}_2\text{O}$

$\text{H}_2\text{O}_2 (\text{aq}) \rightarrow 2\text{OH}^-$

--

Balance electrons  
$4\text{OH}^- + \text{Mn}^{2+} \rightarrow \text{MnO}_2 + 2\text{H}_2\text{O} + 2\text{e}^-$

$2\text{e}^- + \text{H}_2\text{O}_2 (\text{aq}) \rightarrow 2\text{OH}^-$

Add together and Check balance and charges  
$2\text{OH}^- (\text{aq}) + \text{Mn}^{2+}(\text{aq}) + \text{H}_2\text{O}_2(\text{aq}) \rightarrow \text{MnO}_2(\text{s}) + 2\text{H}_2\text{O(l)}$

Note: Students may also choose to show step 3 at the end…
d. If a typical hydrogen peroxide solution is 5.00% by mass (density of solution = 1.04 g/mL), calculate the volume of Mn(NO$_3$)$_2$ (aq) that may be completely reacted with 250.0 mL H$_2$O$_2$ (aq). The concentration of the Mn(NO$_3$)$_2$ solution is 0.150 M.

Given: Volume of H$_2$O$_2$(aq): 250.0 mL  
Concentration of H$_2$O$_2$: 5.00% by mass  
Density of solution: 1.04 g/mL

Find: Volume Mn(NO$_3$)$_2$?

Scheme: find mass H$_2$O$_2$ using given info → moles H$_2$O$_2$ → moles Mn$^{2+}$ → moles Mn(NO$_3$)$_2$

Moles Mn(NO$_3$)$_2$ → volume Mn(NO$_3$)$_2$

Mass H$_2$O$_2$ solution = V xd = (250.0 mL)(1.04 g/mL) = 260.0 g H$_2$O$_2$ solution

Mass H$_2$O$_2$ = 260.0 g H$_2$O$_2$ solution x $\frac{5.00 \text{ g H}_2\text{O}_2}{100 \text{ g solution}}$ = 13.0 g H$_2$O$_2$

Moles H$_2$O$_2$ = 13.0 g H$_2$O$_2$ x $\frac{1 \text{ mol H}_2\text{O}_2}{34.016 \text{ g H}_2\text{O}_2}$ = 0.382 mol H$_2$O$_2$

From the balanced chemical equation, it is seen that the ratio of H$_2$O to Mn$^{2+}$ is 1:1 (Must show this in their response, either in wording or in calculation)

Therefore, 0.382 mol H$_2$O$_2$ x $\frac{1 \text{ mol Mn}^{2+}}{1 \text{ mol H}_2\text{O}_2}$ x $\frac{1 \text{ mol Mn(NO}_3)_2}{1 \text{ mol Mn}^{2+}}$ = 0.382 mol Mn(NO$_3$)$_2$

M = n/V

and V of Mn(NO$_3$)$_2$ = $\frac{n (\text{Mn(NO}_3)_2)}{M (\text{Mn(NO}_3)_2)}$ = $\frac{0.382 \text{ mol Mn(NO}_3)_2}{0.150 \text{ M}}$ = 2.54 L of Mn(NO$_3$)$_2$

= 2.55 L Mn(NO$_3$)$_2$