Part I. Short Answer. Answer 7 of the next 8 questions. If you answer more than 8 questions cross out the one you wish not to be graded. 4 points each.

1. What is the answer to the following expression in the correct number of significant figures?

\[
(0.00821) \times (0.021) \times (298) / 1.523 = \quad 0.034 \\
3.4 \times 10^{-2}
\]

2. How many protons, electrons, and neutrons does an ion of \(^{40}\text{K}^+\) contain?

protons 19, neutrons 21, and electrons 18

<table>
<thead>
<tr>
<th>Name</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>3a. Sodium sulfate dihydrate</td>
<td>Na(_2)SO(_4) \cdot 2\text{H}_2\text{O} )</td>
</tr>
<tr>
<td>3b. Sodium carbonate</td>
<td>Na(_2)CO(_3)</td>
</tr>
<tr>
<td>4a. Chromium (III) chloride hexahydrate</td>
<td>Cr(III)Cl(_3) \cdot 6\text{H}_2\text{O} )</td>
</tr>
<tr>
<td>4b. Iron (III) oxide</td>
<td>Fe(_2)O(_3)</td>
</tr>
<tr>
<td>5a. Hydrochloric acid</td>
<td>HCl</td>
</tr>
<tr>
<td>5b. Ammonium Chloride</td>
<td>NH(_4)Cl</td>
</tr>
</tbody>
</table>

6. Which of the following is NOT an isotope of Ca?

- a. \( \frac{40}{20}X \)
- b. \( \frac{40}{21}X \)
- c. \( \frac{43}{20}X \)
- d. \( \frac{41}{20}X \)
7. If you need $3.6 \times 10^{24}$ molecules of oxalic acid, $\text{H}_2\text{C}_2\text{O}_4$, how many grams of the acid should you weigh out in the laboratory?

\[
3.6 \times 10^{24} \text{ molecules} \cdot \frac{1 \text{ mol}}{6.022 \times 10^{23} \text{ molecules}} \cdot \frac{90.04 \text{ g H}_2\text{C}_2\text{O}_4}{1 \text{ mol}} = \frac{540 \text{ g}}{5.4 \times 10^{2} \text{ g}}
\]

8. Maleic acid, which is used to manufacture artificial resins, has the empirical formula $\text{CHO}$. Its molar mass is 116.1 g/mol. What is its molecular formula?

\[
\frac{116.1 \text{ g/mol}}{29.02 \text{ g/mol}} = \frac{\text{molecular mass}}{\text{Empirical mass}} = 4 \quad \text{C}_4\text{H}_4\text{O}_4
\]

Part II. Short Problems. Answer 4 of the next 5 questions. If you answer more than 4 questions cross out the one you wish not to be graded. For full credit please show your work including intermediate steps. **10 points each.**

9. The element $X$ has three naturally occurring isotopes. The masses (amu) and % abundances of the isotopes are given in the table below. The average atomic mass of the element is ________ amu. (Show your work)

<table>
<thead>
<tr>
<th>Isotope</th>
<th>Percent Abundance</th>
<th>Mass (amu)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^{221}X$</td>
<td>74.22</td>
<td>220.9</td>
</tr>
<tr>
<td>$^{220}X$</td>
<td>12.78</td>
<td>220.0</td>
</tr>
<tr>
<td>$^{218}X$</td>
<td>13.00</td>
<td>218.1</td>
</tr>
</tbody>
</table>

\[
0.7422 \times 220.9 \text{ amu} + 0.1278 \times 220.0 \text{ amu} + 0.1300 \times 218.1 \text{ amu} = 220.42 \text{ amu}
\]
10. Calcium carbide (CaC₂) reacts with water to produce acetylene (C₂H₂):

\[ \text{CaC}_2 (s) + 2\text{H}_2\text{O} (g) \rightarrow \text{Ca(OH)}_2 (s) + \text{C}_2\text{H}_2 (g) \]

Production of 13 g of C₂H₂ requires consumption of \( 18 \) g of H₂O?

\[
\begin{align*}
13 \text{g C}_2\text{H}_2 & \cdot \frac{1 \text{mol C}_2\text{H}_2}{26.04 \text{g C}_2\text{H}_2} & \cdot \frac{2 \text{mol H}_2\text{O}}{1 \text{mol C}_2\text{H}_2} & \cdot \frac{18.02 \text{g H}_2\text{O}}{1 \text{mol H}_2\text{O}} = 17.99 \text{g H}_2\text{O} \\
\end{align*}
\]

2 sfg fgs: \( [18.9 \text{ g H}_2\text{O}] \)

11. The original method of making ammonia was to react calcium cyanamide with water according to the following reaction.

\[ \text{CaCN}_2 (s) + \text{H}_2\text{O(l)} \rightarrow \text{CaCO}_3 (s) + \text{NH}_3(g) \]

Balance the above equation.

\[ \text{CaCN}_2 (s) + 3 \text{H}_2\text{O(l)} \rightarrow \text{CaCO}_3 (s) + 2 \text{NH}_3(g) \]

12. Determine total moles of ions in a solution made by diluting 50.0 mL of a 0.874 M solution of sodium carbonate to a total volume of 250.0 mL.

\[ \text{Na}_2\text{CO}_3 (aq) \rightarrow 2\text{Na}^+(aq) + \text{CO}_3^{2-}(aq) \]

3 moles of ions produced
per mol \( \text{Na}_2\text{CO}_3 \)

0.874 M \( \text{Na}_2\text{CO}_3 \), 0.050 L = 0.0437 moles \( \text{Na}_2\text{CO}_3 \)

0.0437 moles \( \text{Na}_2\text{CO}_3 \), \( \frac{3 \text{ moles ions}}{1 \text{ mol } \text{Na}_2\text{CO}_3} = 0.13 \) moles ions

3 sfg fgs: \( 0.131 \) moles of ions
13. Determine the percent by weight of O in NaIO₃. (Report your answer with three significant figures.)

\[
\frac{\text{Mass O}}{\text{Molecular mass}} = \frac{15.999 \text{ g O}}{(22.99 + 126.90 + 3 \times 15.999)} = \frac{15.999 \text{ g O}}{197.887 \text{ g NaIO₃}}
\]

\[0.080849 \times 100\% = 8.0849 \% \rightarrow 8.08\%
\]

Depending on how you rounded the mass of O, you may have calculated 8.09%.

Part III. Problems. Answer 2 of the next 3 questions. If you answer more than 2 questions cross out the one you wish not to be graded. For full credit please show your work including intermediate steps. 16 points each.

14. The molecule known as MEH-PPV is used in making a special kind of solar cell called an organic photovoltaic. When a 10.0 g sample of MEH-PPV is combusted, it produced 28.7 g of CO₂ and 9.13 g of H₂O. What is the empirical formula of MEH-PPV?

\[
\text{mass C: 28.7 g CO₂} \times \frac{1 \text{ mol CO₂}}{44.01 g \text{ CO₂}} = 0.651 \text{ mol C}
\]
\[
\text{moles C: 7.832 g C} \times \frac{1 \text{ mol C}}{12.01 g \text{ C}} = 0.651 \text{ mol C}
\]
\[
\text{mass H: 9.13 g H₂O} \times \frac{1 \text{ mol H₂O}}{18.02 g \text{ H₂O}} = 0.507 \text{ mol H}
\]
\[
\text{moles H: 1.023 g H} \times \frac{1 \text{ mol H}}{1.01 g \text{ H}} = 1.013 \text{ mol H}
\]
\[
\text{mass O: 10.0 g substance} - 7.832 \text{ g C} - 1.023 \text{ g H} = 1.145 \text{ g O}
\]
\[
\text{moles O: 1.145 g O} \times \frac{1 \text{ mol O}}{16.00 \text{ g O}} = 0.07156 \text{ mol O}
\]

Divide by moles O (smallest)
\[
\frac{0.651 \text{ mol C}}{0.07156} = 9 \quad \frac{1.013 \text{ mol H}}{0.07156} = 14 \quad \frac{0.07156 \text{ mol O}}{0.07156} = 1
\]

\[\text{C₉H₁₄O}\]
15. Aspirin is produced by the reaction of salicylic acid (M = 138.1 g/mol) and acetic anhydride (M= 102.0 g/mol).

\[ 2\text{C}_7\text{H}_6\text{O}_3 (s) + \text{C}_4\text{H}_6\text{O}_3 (l) \rightarrow 2\text{C}_9\text{H}_8\text{O}_4 (s) + \text{H}_2\text{O} (l) \] (unbalanced)

salicylic acid  acetic anhydride  aspirin

If you mix 100.0 g of each of the reactants, how many grams of aspirin (M = 180.2 g/mol) can theoretically be obtained?

Determine Limiting Reagent

\[
\begin{align*}
100.0 \text{ g} \text{C}_7\text{H}_6\text{O}_3 & \quad \frac{1 \text{ mol} \text{C}_7\text{H}_6\text{O}_3}{138.1 \text{ g} \text{C}_7\text{H}_6\text{O}_3} \quad \frac{2 \text{ mol} \text{C}_9\text{H}_8\text{O}_4}{2 \text{ mol} \text{C}_7\text{H}_6\text{O}_3} = 0.724 \text{ mol} \text{C}_9\text{H}_8\text{O}_4 \\
100.0 \text{ g} \text{C}_4\text{H}_6\text{O}_3 & \quad \frac{1 \text{ mol} \text{C}_4\text{H}_6\text{O}_3}{102.0 \text{ g} \text{C}_4\text{H}_6\text{O}_3} \quad \frac{2 \text{ mol} \text{C}_9\text{H}_8\text{O}_4}{1 \text{ mol} \text{C}_4\text{H}_6\text{O}_3} = 1.96 \text{ mol} \text{C}_9\text{H}_8\text{O}_4
\end{align*}
\]

\text{C}_7\text{H}_6\text{O}_3 \ \text{is the limiting reagent because it produced the smallest amount of product, C}_9\text{H}_8\text{O}_4\]

\[
0.724 \text{ mol} \text{C}_9\text{H}_8\text{O}_4 \cdot \frac{180.2 \text{ g} \text{C}_9\text{H}_8\text{O}_4}{1 \text{ mol} \text{C}_9\text{H}_8\text{O}_4} = 130.46 \text{ g} \rightarrow 130.5 \text{ g}
\]

16. The valuable compound diborane, B\(_2\)H\(_6\), can be made by the reaction

\[ 2 \text{NaBH}_4 (s) + \text{I}_2 (s) \rightarrow \text{B}_2\text{H}_6 (g) + 2 \text{NaI(s)} + \text{H}_2 (g) \]

You use 1.203 g of NaBH\(_4\) and excess iodine. If you isolate 0.295 g of B\(_2\)H\(_6\), what is the percentage yield of B\(_2\)H\(_6\) from the reaction?

\[
\begin{align*}
1.203 \text{ g} \text{NaBH}_4 & \cdot \frac{1 \text{ mol} \text{NaBH}_4}{37.841 \text{ g} \text{NaBH}_4} \cdot \frac{1 \text{ mol} \text{B}_2\text{H}_6}{2 \text{ mol} \text{NaBH}_4} = 0.044002 \text{ g} \text{B}_2\text{H}_6 \\
& \text{theoretically produced}
\end{align*}
\]

\[
\frac{0.295 \text{ g} \text{B}_2\text{H}_6}{0.44002 \text{ g} \text{B}_2\text{H}_6} \times 100\% = 67.0\%
\]

only 3 sig figs because of 0.295.