1) Balance the following chemical reactions (4pts each) and provide the names for each compound. (2pts each)

\[ \text{P}_4\text{O}_6(s) + 6\text{H}_2\text{O}(l) \rightarrow 4\text{H}_3\text{PO}_4 \]

**Hydrolysis of phosphorus**

\[ \text{CaSiO}_2(s) + 6\text{HF}(g) \rightarrow \text{SiF}_4(g) + \text{CaF}_2(s) + 3\text{H}_2\text{O}(l) \]

**Hydrofluoric acid**

2) Draw the COMPLETE Lewis structure of the carbonate ion. (6 pts)

Please indicate the a) atomic formal charges (2 pts), b) type of hybrid orbitals involved in bonding around the central atom (3 pts), and c) the shape of the ion. (3 pts)

![Lewis structure of carbonate ion]

3) Describe the periodic trend of electronegativity, be sure to indicate both what it is measuring and how it changes across the periodic table. BRIEFLY provide the chemical reasoning behind the trend. A couple sentences should be plenty. (10 pts)

"As you go up and to the left (except noble gases) the electronegativity increases. As you go to the right, both the charge and the radius decreases, but the charge increases, making it more electronegative."

The charge on the e- gets closer to the nucleus, making it more difficult for it to work effectively.

..."
4) Select the alternative energy source (other than the one that you presented) that you think will be the most advantageous for the US to develop. List 3 advantages to this energy source as well as 2 drawbacks. (10 pts) If you can summarize the advantage in just a couple words that is fine, you need not completely describe the why it is an advantage/disadvantage. Please note that selecting the energy source you presented, will result in a 0 for the question.

**Energy Source:**

<table>
<thead>
<tr>
<th>Advantages:</th>
<th>Disadvantages:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td></td>
</tr>
</tbody>
</table>

5) Halogens will react with alkanes in the presence of light. Show the product of the reaction that occurs between ethane and an equal amount of bromine. (8 pts)

\[
\text{C}_2\text{H}_6 + \text{Br}_2 \xrightarrow{\text{hv}} 2\text{C}_2\text{H}_5\text{Br} + \text{HBr}
\]

The light acts to initially break the halogen-halogen bond. Knowing that the bond energy of Br-Br is 193 kJ/mol, will light of wavelength 725 nm have enough energy to initiate the reaction? (2 pts for answer, 10 pts for reasoning). If not, what is the minimum wavelength of light necessary to induce the reaction? If so, how much extra energy is provided by this frequency of light? (7 pts)

\[
E = \frac{h \nu}{\lambda} = \frac{6.626 \times 10^{-34} \text{ J s}}{2.94 \times 10^8 \text{ m/s}} \times \frac{2.94 \times 10^8 \text{ m/s}}{725 \times 10^{-9} \text{ m}} = 165 \text{ kJ/mole}
\]

\[
\text{E} = \frac{h \nu}{\lambda} = \frac{6.626 \times 10^{-34} \text{ J s}}{2.94 \times 10^8 \text{ m/s}} \times \frac{2.94 \times 10^8 \text{ m/s}}{193 \times 10^{-9} \text{ m}} = 618 \text{ nm light}
\]
6) Many people contributed to the slow development of our current understanding of the atomic structure. Which of the following people made each of the discoveries/conceptual advances below: (6 pts)

Democritus, Antoine Lavoisier, Proust, John Dalton, JJ Thompson, Robert Millikan, Ernest Rutherford, Marie Curie, Niels Bohr, DeBroglie, Max Planck, Erwin Schrödinger

a) Discovered the nucleus of the atom
   \textbf{Rutherford}

b) Discovered atomic radiation
   \textbf{Curie}

c) Determined the charge to mass ratio of the electron
   \textbf{Thompson}

7) On the first day of class questions, Melissa asked “why do pennies (copper) turn green?” Using the $\Delta H_f$ below, show why copper when exposed to air forms the green copper(II)oxide. Provide both the equation for the reaction (6 pts) and reasoning for why the reaction occurs (3 pts).

$\Delta H_f$ for select compounds. All values are in kJ/mol

<table>
<thead>
<tr>
<th>Compound</th>
<th>Energy</th>
<th>Compound</th>
<th>Energy</th>
<th>Compound</th>
<th>Energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>H$_2$O (l)</td>
<td>-285.8</td>
<td>FeO(s)</td>
<td>-272</td>
<td>CuO(s)</td>
<td>-156.06</td>
</tr>
<tr>
<td>H$_2$O (g)</td>
<td>-241.8</td>
<td>Fe$_2$O$_3$ (s)</td>
<td>-825.5</td>
<td>Cu(OH)$_2$ (s)</td>
<td>-449.8</td>
</tr>
<tr>
<td>H$_2$O$_2$ (l)</td>
<td>-187.8</td>
<td>Fe$_3$O$_4$ (s)</td>
<td>-1118.4</td>
<td>Cu$_2$(O) (s)</td>
<td>-168.6</td>
</tr>
</tbody>
</table>

$2\text{Cu} + \text{O}_2 \rightarrow 2\text{CuO}$

Thus the $\Delta H_{rxn}$ for this is just $2x \Delta H_f$ for CuO. Since $\Delta H_f$ for CuO is exothermic this reaction will also be exothermic and therefore energetically favorable.
8) The primary fatty acid in almond oil is oleic acid, C₁₈H₃₄O₂, FW=282.45.30 amu. Write the reaction for the combustion of lauric acid. (10 pts)

\[ \text{C}_1_{8}\text{H}_{34}\text{O}_2 + 17\text{O}_2 \rightarrow 17\text{CO}_2 + 17\text{H}_2\text{O} \]

Your body uses this same net reaction to provide energy for your body. Determine the \( \Delta H_{\text{fus}} \) for the combustion of oleic acid using the information below. (15 pts)

Show how many dietary Calories are in exactly 1 gram of oleic acid. (10 pts) (Remember 1 dietary Calorie = 1000 calories.) Since most fats have approximately the same energy density you can use the dietary information given for Bertolli Olive oil to determine if you have gotten approximately the correct value.

AFH₁ for select compounds. All values are in kJ/mol.

<table>
<thead>
<tr>
<th>Compound</th>
<th>Energy</th>
<th>Compound</th>
<th>Energy</th>
<th>Compound</th>
<th>Energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>H₂O (l)</td>
<td>-285.8</td>
<td>CO (g)</td>
<td>-110.5</td>
<td>Lauric acid</td>
<td>-774.6</td>
</tr>
<tr>
<td>H₂O (g)</td>
<td>-241.8</td>
<td>CO₂ (g)</td>
<td>-393.5</td>
<td>Stearic acid</td>
<td>-947.3</td>
</tr>
<tr>
<td>H₂O₂ (l)</td>
<td>-187.8</td>
<td>CH₄ (g)</td>
<td>-74.87</td>
<td>Oleic acid</td>
<td>-814.5</td>
</tr>
</tbody>
</table>

\[ \Delta H_{\text{fus}} = 18(-244.1) + 17(-393.5) - 84.5 - 0 \approx -1114.7 \text{ kJ/mol} \]

\[ \text{H}_{28\text{C}}\text{O}_{58\text{H}} \rightarrow 94.5 - 0 = 10379.1 \text{ kJ} \]

\[ \frac{1}{2} \text{C}_1_{8}\text{H}_{34}\text{O}_2 \left( \frac{1114.7 \text{ kJ}}{1 \text{ mol}} \right) \approx 9.4 \text{ or } \text{C}_1/10 \]
9) Alanine and valine (the two amino acids shown below) can react to form a peptide bond (repetition of the process will lead to longer amino acid chains known as proteins). Draw the reaction between these two amino acids (5 pts) and indicate the electrostatic attraction that begins the reaction (2 pts).

![Reaction Diagram]

Using the table of bond energies below, determine the ΔH_{\text{rxn}} for the reaction that you have drawn above. (12 pts) Is this reaction enthalpically favorable? (1 pt) Why? (2 pts)

<table>
<thead>
<tr>
<th>Bond</th>
<th>Energy (kJ/mol)</th>
<th>Bond</th>
<th>Energy (kJ/mol)</th>
<th>Bond</th>
<th>Energy (kJ/mol)</th>
</tr>
</thead>
<tbody>
<tr>
<td>H-H</td>
<td>436</td>
<td>O=O</td>
<td>498</td>
<td>C-N</td>
<td>305</td>
</tr>
<tr>
<td>C-H</td>
<td>413</td>
<td>C-O</td>
<td>385</td>
<td>C-N</td>
<td>615</td>
</tr>
<tr>
<td>C-C</td>
<td>346</td>
<td>C=O</td>
<td>745</td>
<td>C=N</td>
<td>887</td>
</tr>
<tr>
<td>O-H</td>
<td>463</td>
<td>N-H</td>
<td>391</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\[ \Delta H = \sum \text{Bond break} - \sum \text{Bond make} \]

\[ \Delta H = 358 + 385 - 463 = -19 \text{kJ} \]

\[ \text{ΔH < 0} \]
10) When 56.6 g of calcium and 30.5 g of nitrogen gas undergo a reaction that has a 93.6% yield, what mass of calcium nitride forms? (20 pts)

3 Ca (s) + N₂ (g) → Ca₃N₂ (s)

56.6g Ca

6.2g Ca

3 mol Ca

3 mol Ca

4.8g Ca

1 mol Ca

1 mol Ca₃N₂

2 mol Ca₃N₂

64.5

93.6 g Ca₃N₂ formed

60.5 g Ca₃N₂ formed

Ca₃N₂ % yield

3.15% yield
11) A sample of oxalic acid was dissolved in 150 mL of water and then diluted in a volumetric flask to give exactly 500.0 mL of total solution. If 14.3 mL of this solution is completely titrated by 41.65 mL of 0.00052 M LiOH, what mass of oxalic acid was originally dissolved? (15 pts)

\[
\text{0.04165 mL} \times \frac{5.2 \times 10^{-4} \text{ mole}}{1 \text{ L}} \times \frac{6 \text{ mol H}_2 \text{O}}{1 \text{ mol LiOH}} \times \frac{500 \text{ mL}}{14.3 \text{ mL}} = 0.0814
\]

Draw a hybrid orbital picture showing the structure of oxalic acid. Be sure to explicitly indicate the types of orbital associated with each bond present. (10 pts)