I. Multiple Choice (for those with an asterisk, you must show work)

*1. Which compound contains the highest percentage of magnesium by mass?
   (A) MgNH₄PO₄  (B) Mg(H₂PO₄)₂  
   (C) Mg₂P₄O₇  (D) Mg₃(PO₄)₂

*2. Vanillin, C₈H₈O₃ (M = 152 g/mol), is the molecule responsible for the vanilla flavor in food. How many oxygen atoms are present in a 45.0 mg sample of vanillin?
   (A) 1.78 × 10²⁰  (B) 5.35 × 10²⁰  
   (C) 1.78 × 10²³  (D) 5.35 × 10²³

3. Five successive determinations of the density of an alloy gave the following results: 10.29 g/mL, 9.95 g/mL, 10.06 g/mL, 9.89 g/mL, 10.18 g/mL. What value should be reported for the density of this alloy?
   (A) 10.074 g/mL  (B) 10.07 ± 0.16 g/mL  
   (C) 10.1 ± 0.2 g/mL  (D) 1.0 × 10¹ g/mL

*4. Complete combustion of 1.00 g of the hydrocarbon pagodane gives 3.38 g carbon dioxide. What is the empirical formula of pagodane?
   (A) CH  (B) CH₂  (C) C₂H₅  (D) C₃H₈

5. One mole of which hydrocarbon requires 8 mol O₂ to achieve complete combustion to give carbon dioxide and water?
   (A) C₃H₈  (B) C₄H₁₀  (C) C₅H₁₀  (D) C₃H₁₂

*6. Aspirin, C₉H₈O₄, is prepared by the acetylation of salicylic acid, C₇H₆O₃, according to the following equation:
   \[ \text{C}_7\text{H}_6\text{O}_3 + (\text{CH}_3\text{CO})_2\text{O} \rightarrow \text{C}_9\text{H}_8\text{O}_4 + \text{CH}_3\text{COOH} \]
   If the yield of this reaction is 83%, what mass of salicylic acid would be required to prepare 1.0 kg of aspirin?
   (A) 0.77 kg  (B) 0.92 kg  
   (C) 1.2 kg  (D) 1.3 kg

7. Which group of ions contains only ions you would predict as “stable”?
   A. Li⁺², Fe⁺², Ca⁺²  B. Mg⁺², Cr⁺³, O₂⁻  
   C. Ca⁺², Fe⁺³, Al⁺³  D. F⁻², Al⁺⁴, Na⁺

8. If a sample of matter is uniform throughout and cannot be separated into other substances by physical means, it is _______.
   A. a compound  B. either a compound or an element  
   C. a homogeneous mixture  D. a heterogeneous mixture  
   E. an element
9. For the following arithmetic operation, what is the proper number of significant figures for the answer?

\[
(0.97269 + 0.041) \div 4.7000 \times 10^6 =
\]

A. 1  B. 2  C. 3  D. 4  E. 5

10. Identify the description of an atom.
   A. neutrons and electrons in nucleus; protons in orbitals
   B. neutrons in nucleus; protons and electrons in orbitals
   C. protons and neutrons in nucleus; electrons in orbitals
   D. protons and electrons in nucleus; neutrons in orbitals
   E. electrons in nucleus; protons and neutrons in orbitals

*11. How many C₂H₄ molecules are contained in 45.8 mg of C₂H₄?
   A. 9.83 × 10²⁰ C₂H₄ molecules
   B. 7.74 × 10²⁶ C₂H₄ molecules
   C. 2.71 × 10³⁰ C₂H₄ molecules
   D. 3.69 × 10³³ C₂H₄ molecules
   E. 4.69 × 10³³ C₂H₄ molecules

II. Short Answer (all answers must show work)

1. **Empirical Formula:** A compound has the following elemental analysis:

<table>
<thead>
<tr>
<th>Element</th>
<th>% composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>49.48</td>
</tr>
<tr>
<td>H</td>
<td>5.19</td>
</tr>
<tr>
<td>N</td>
<td>28.85</td>
</tr>
<tr>
<td>O</td>
<td>16.48</td>
</tr>
</tbody>
</table>

What is its empirical formula? This compound's molar mass is around 190 g/mol. What is its molecular formula? Use online resources to determine the most likely common name for this chemical.

2. **Empirical Formula:** A kidney stone was analyzed and found to contain 0.360 g Ca, 0.575 g O, and 0.216 g C. What is the empirical formula of the compound? Use online resources to determine the most likely common name for this chemical. Please show your calculations for full credit.
3. **Combustion Analysis:** A sample of a blue crystal was found at an industrial laundry facility outside of Albuquerque, NM. The only four elements possibly in the compound were determined to be C, H, N, and O. Complete combustion of a 0.6250 g sample of the unknown crystal with excess O₂ produced 1.8546 g of CO₂ and 0.5243 g of H₂O. A separate analysis of a 0.8500 g sample of the blue crystal was found to produce 0.0465 g NH₃. The molar mass of the substance was found to be about 310 g/mol. What is the molecular formula of the unknown crystal? Use online resources to determine the most likely common name for this chemical.

4. **Hydrated Compound:** A hydrate of nickel(II) sulfate has the following formula: NiSO₄•xH₂O. The water in a 0.250 g sample of the hydrate was driven off by heating. The remaining sample had a mass of 0.171 g. Find the number of waters of hydration (x) in the hydrate.
5. An organic compound was synthesized & a sample of it was analyzed & found to contain only C, H, N, O, & Cl. It was observed that when a 0.150 g sample of the compound was burned, it produced 0.138 g CO$_2$ & 0.0566 g H$_2$O. All the nitrogen in a different 0.200 g sample of the compound was converted to NH$_3$, which was found to weigh 0.0238 g. Finally, the chlorine in a 0.125 g sample of the compound was converted to Cl$^-\text{and}$ by reacting it with AgNO$_3$, all of the chlorine was recovered as the solid AgCl. The AgCl, when dried was found to weigh 0.251 g. What is the empirical formula of this compound?

6. For the reaction,

$$2 \text{H}_2(\text{g}) + \text{O}_2(\text{g}) \rightarrow 2 \text{H}_2\text{O}(\text{g})$$

a schematic picture of hydrogen and oxygen molecules is shown in the left-hand square below. In this picture, a smaller filled circle is a hydrogen atom and a larger empty circle is an oxygen atom.

In the box on the right, please draw the correct number of product molecules that could form and the correct number(s) of reactant(s) left over. Assume that the reaction creates as many product molecules as possible.