(1) (20 pts, 2 pts each blank) Fill in the blanks. (Use one word or chemical formula in each blank. You may use the same word more than once if appropriate.

(a) A $^{31}$P atom contains 15 negatively charged ELECTRONS, 15 positively charged PROTONS and 16 NEUTRONS that have no charge.

(b) The formula of potassium molybdate is $K_2MoO_4$, so the charge on the molybdate ion must be $-2$.

(c) The molarity of a solution is defined as the number of MOLES of solute per LITER of solution.

(d) A(n) CATION is an atom or group of atoms carrying a positive charge.

(e) When a hydrocarbon is burned in oxygen, the resulting chemical reaction is called COMBUSTION.

(f) If a substance dissolves in water to produce a solution that conducts electricity, that substance is called a(n) ELECTROLYTE.

(g) Acetic acid is only partially dissociated in solution, so it is known as a(n) WEAK acid.

(2) (12 pts, 4 pts each) Imagine that we had a balance that could compare the masses of small numbers of atoms of different elements. The figures below show the (hypothetical) results of 2 such experiments. The letters beside each balance pan identify the elements being weighed. (These are NOT actual elements! Your answer should be based ONLY on these pictures.)

![Balance diagrams](image)

Please circle your choice for each question below:

(a) Of elements C and E, which has the greater molar mass?
   - element C
   - element E
   - neither, they’re equal

(b) Of elements F and G, which has more atoms per gram?
   - element F
   - element G
   - neither, they’re equal

(c) Of elements F and G, which has more atoms per mole?
   - element F
   - element G
   - neither, they’re equal

(For grading)

<table>
<thead>
<tr>
<th>Scores</th>
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<tr>
<td>1 /20</td>
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<td>9 /12</td>
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<td>Tot. /100</td>
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F G C E
(3) (10 points) In the first row of blanks beneath each of the following compounds, classify them as follows: weak acid (wa), strong acid (sa), weak base (wb), strong base (sb), or as a salt (s) that is neither acid or basic. In the second row of blanks, classify the same compounds as a weak electrolyte (we), strong electrolyte (se), or nonelectrolyte (ne).

<table>
<thead>
<tr>
<th>HNO₃</th>
<th>NH₃</th>
<th>Sr(OH)₂</th>
<th>KCl</th>
<th>CH₃COOH</th>
</tr>
</thead>
<tbody>
<tr>
<td>wa</td>
<td>wb</td>
<td>sb</td>
<td>s</td>
<td>wa</td>
</tr>
<tr>
<td>se</td>
<td>we</td>
<td>se</td>
<td>se</td>
<td>we</td>
</tr>
</tbody>
</table>

(4) (8 points) The following full sets of potential compounds are made up of common cations and anions. Which full sets are most likely to actually exist? (All 3 compounds in a set must be sensible to qualify.) There may be more than one correct choice; enter ALL the correct letters, in alphabetical order.

(a) Rb(SO₄)₂, CaCO₃, ZnClO₄  (b) (NH₄)₂PO₄, NaCO₃, KNO₃  (c) Ca₃(PO₄)₂, Ag₂SO₄, NH₄NO₃
(d) K₂SO₄, KClO₄, Ca(OH)₂  (e) (NH₄)₂PO₄, K₂CO₃, Zn₃(PO₄)₂

Ans. 4 C, D.
Questions 5 - 9 – show all work (50 pts)

(5) * (11 points) Suppose that equal volumes of 0.2017 M nitric acid (HNO₃) and 1.876 M magnesium nitrate (Mg(NO₃)₂) are mixed. Find the molarity of nitrate ions in the resulting solution. (Assume that the volume of the final mixture is the sum of the volumes of the individual solutions. As long as the volumes of the two solutions are the same, the result does not depend on the actual volume used. So you can choose any convenient volume if you’d like.)

\[ V_{\text{HNO}_3} = V_{\text{Mg(NO}_3)_2} = 0.5 \text{ L} \]
\[ V_{\text{total}} = V_{\text{HNO}_3} + V_{\text{Mg(NO}_3)_2} = 1 \text{ L} \]

\[ (0.5 \text{ L}) \left( 0.2017 \frac{\text{mol HNO}_3}{\text{L}} \right) \left( \frac{1 \text{ mol NO}_3^-}{1 \text{ mol HNO}_3} \right) = 0.10085 \text{ mol NO}_3^- \]

\[ (0.5 \text{ L}) \left( 1.876 \frac{\text{mol Mg(NO}_3)_2}{\text{L}} \right) \left( \frac{2 \text{ mol NO}_3^-}{1 \text{ mol Mg(NO}_3)_2} \right) = 1.876 \text{ mol NO}_3^- \]

Total moles of NO₃⁻ = 0.1009 + 1.876 = 1.97865 mol NO₃⁻

\[ M_{\text{NO}_3^-} = \frac{\text{total moles of NO}_3^-}{V_{\text{total}}} = \frac{1.97865 \text{ mol NO}_3^-}{1 \text{ L}} \]

\[ M_{\text{NO}_3^-} = 1.977 \text{ M} \]

(6) * (11 points) Shown below is the molecular structure of tetrahydrocannabinol (THC), the principal psychoactive constituent of cannabis. THC in Cannabis is assumed to be involved in self-defense, perhaps against herbivores. THC also possesses high UV-B (280–315 nm) absorption properties, which may protect the plant from harmful UV radiation exposure.

![Tetrahydrocannabinol (THC)](image)

((--)-(6aR,10aR)-6,6,9-Trimethyl-3-pentyl-6a,7,8,10a-tetrahydro-6H-benzo[c]chromen-1-ol)

(a) * (5 pts) Give the molecular formula for THC.
C₂₁H₃₀O₂

(b) * (3 pts) Assuming your answer is correct; calculate the molar mass of THC.

\[ (21 \times 12.01 \text{ g mol}^{-1} \text{ C}) + (30 \times 1.008 \text{ g mol}^{-1} \text{ H}) + (2 \times 16.00 \text{ g mol}^{-1} \text{ O}) = 314.45 \text{ g mol}^{-1} \text{ THC} \]

(a) * (3 pts) How many carbon atoms are there in 1.0 g of THC?

moles of THC = (1.0 g THC) \( \frac{\text{mol THC}}{314.45 \text{ g}} \) = 3.180 \times 10^{-3} \text{ mol THC}

moles of C atoms = (3.180 \times 10^{-3} \text{ mol THC}) \left( \frac{21 \text{ mol C}}{\text{mol THC}} \right) = 6.678 \times 10^{-2} \text{ mol C atoms}

\[ N_C = \left( 6.678 \times 10^{-2} \text{ mol C atoms} \right) \left( \frac{6.022 \times 10^{23} \text{ C atoms}}{1 \text{ mol C}} \right) = 4.02 \times 10^{22} \text{ C atoms} \]
(7) (8 points) Pyrrole has the molecular formula C₄H₅N. When pyrrole is completely combusted by reaction with O₂, the products are CO₂, H₂O, and N₂. Write a balanced equation for this reaction. Put the answer you want graded in the box below; you can use the rest of the space for your work, but only the answer will be graded.

\[
4\text{C}_4\text{H}_5\text{N} + 21\text{O}_2 \rightarrow 16\text{CO}_2 + 10\text{H}_2\text{O} + 2\text{N}_2
\]

(8) (8 points) Seawater contains significant amounts of uranium in the form of aqueous uranyl, UO₂²⁺, ions. The average UO₂²⁺ content of the oceans has been estimated as \(3.9 \times 10^{-3}\) mg UO₂²⁺ per kg of seawater, and the density of seawater is about 1.03 g/mL. Although the concentration of uranium is small, the oceans are large: the total volume of the world’s oceans is about \(3.5 \times 10^{20}\) gallons. The price of uranium oxide (U₃O₈) is currently $37.50 per lb. Based on the cost of U₃O₈, estimate the total dollar value of all of the uranium dissolved in the oceans.

\[1\text{ gallon} = 3.7854\text{ L}\]
\[1\text{ lb} = 454\text{ g}\]

\[3.5 \times 10^{20}\text{ gallon} \left(\frac{3.7854\text{ L}}{\text{gallon}}\right) = 1.325 \times 10^{21}\text{ L seawater}\]
\[1.03\text{ g/mL} = 1.03\text{ kg/L}\]

The total mass of seawater is thus:
\[1.325 \times 10^{21}\text{ L} \left(\frac{1.03\text{ kg}}{\text{L}}\right) = 1.365 \times 10^{21}\text{ kg of seawater}\]

The total mass of UO₂⁺:
\[1.365 \times 10^{21}\text{ kg seawater} \left(\frac{3.9 \times 10^{-3}\text{ mg UO}_2^+}{\text{kg seawater}}\right) \left(\frac{1\text{ g}}{1000\text{ mg}}\right) = 5.322 \times 10^{15}\text{ g UO}_2^+\]

Mass of U₃O₈ = 840 g/mol and the mass of UO₂⁺ = 270 g/mol. Each mole of U₃O₈ has 3 moles of U. Therefore, the mass of U₃O₈ provided by \(5.322 \times 10^{15}\text{ g of UO}_2^+\) can be expressed as:

\[
\text{mass}_{\text{U}_3\text{O}_8} = 5.322 \times 10^{15}\text{ g UO}_2^+ \left(\frac{\text{mol UO}_2^+}{270\text{ g UO}_2^+}\right) \left(\frac{1\text{ mol U}}{1\text{ mol UO}_2^+}\right) \left(\frac{1\text{ mol U}_3\text{O}_8}{3\text{ mol U}}\right) \left(\frac{842\text{ g U}_3\text{O}_8}{1\text{ mol U}_3\text{O}_8}\right)
\]
\[
= (5.322 \times 10^{15}) \left(\frac{842}{270 \times 3}\right) \text{ g U}_3\text{O}_8
\]
\[
= 5.532 \times 10^{15}\text{ g U}_3\text{O}_8
\]

\[(5.532 \times 10^{15}\text{ g U}_3\text{O}_8) \left(\frac{1\text{ lb}}{454\text{ g}}\right) = 1.219 \times 10^{13}\text{ lb U}_3\text{O}_8\]

Total Dollar Value = \(1.219 \times 10^{13}\text{ lb U}_3\text{O}_8 \left(\frac{$37.50}{\text{lb}}\right) = $4.57 \times 10^{14}\)
(9) (12 points) A solution contains both Ca\(^{2+}\) and Pb\(^{2+}\) ions. A 75.0-mL sample of this solution was treated with a 0.528 M NaF solution and 80.7 mL of the NaF solution was needed to precipitate all of the Ca\(^{2+}\) and Pb\(^{2+}\) as CaF\(_2\)(s) and PbF\(_2\)(s). The precipitate was dried and weighed and had a total mass of 4.112 g. What was the concentration of Ca\(^{2+}\) in the original solution?

\[ n = \text{moles} \quad f = \text{formula weight (molar mass)} \quad m = \text{mass} \]

\[ n_{F^-} = (0.0807 \text{ mL}) \left( \frac{0.528 \text{ mol NaF}}{L} \right) \left( \frac{1 \text{ mol}}{1 \text{ mol NaF}} \right) = 0.04261 \text{ mol F}^- \]

The total mass of precipitate formed is equal to the sum of its constituents:
\[ m_{\text{total}} = m_{F^-} + m_{Pb^{2+}} + m_{Ca^{2+}} \]

Because \( nf = m \):
\[ m_{\text{total}} = n_{F^-} f_{F^-} + n_{Pb^{2+}} f_{Pb^{2+}} + n_{Ca^{2+}} f_{Ca^{2+}} = 4.112 \text{ g} \]

Mole balance equation:
\[ n_{Pb^{2+}} + n_{Ca^{2+}} = \frac{n_{F^-}}{2} \]

Solve for moles of Pb\(^{2+}\):
\[ n_{Pb^{2+}} = \frac{n_{F^-}}{2} - n_{Ca^{2+}} \]

Substitute \( n_{Pb^{2+}} \) and solve for \( n_{Ca^{2+}} \):
\[ n_{F^-} f_{F^-} + \left( \frac{n_{F^-}}{2} - n_{Ca^{2+}} \right) f_{Pb^{2+}} + n_{Ca^{2+}} f_{Ca^{2+}} = 4.112 \text{ g} \]
\[ n_{F^-} f_{F^-} + \left( \frac{n_{F^-}}{2} - n_{Ca^{2+}} \right) f_{Pb^{2+}} + n_{Ca^{2+}} f_{Ca^{2+}} = 4.112 \text{ g} \]
\[ \left( 0.04261 \text{ mol} \times \frac{19.00 \text{ g}}{\text{mol}} \right) + \frac{1}{2} \left( 0.04261 \text{ mol} \times \frac{207.2 \text{ g}}{\text{mol}} \right) + n_{Ca^{2+}} (-207.2 + 40.08) \frac{\text{g}}{\text{mol}} = 4.112 \text{ g} \]
\[ 0.8096 \text{ g} + 4.413 \text{ g} - \left( 167.12 \text{ n}_{Ca^{2+}} \right) \frac{\text{g}}{\text{mol}} = 4.112 \text{ g} \]
\[ n_{Ca^{2+}} = \frac{4.112 - 0.8096 - 4.413}{-167.12} \text{ mol Ca}^{2+} \]
\[ n_{Ca^{2+}} = 0.0066455 \text{ mol Ca}^{2+} \]

Divide by the sample volume to find the concentration:
\[ c_{Ca^{2+}} = \frac{0.0066455 \text{ mol Ca}^{2+}}{75.0 \text{ mL}} \left( \frac{1 \text{ mL}}{1000 \text{ mL}} \right) = 0.0886 \text{ M} \]