On the last page of this exam, you’ve been given a periodic table and some physical constants. You may want to tear that page off to use during the exam – you don’t need to turn it in with the rest of the exam.

The exam contains 9 problems, with 5 numbered pages. You have the full 75 minutes to complete the exam. **Please show ALL your work as clearly as possible** – this will help us award you partial credit if appropriate. Even correct answers without supporting work may not receive credit. You may use an approved calculator for the exam, one without extensive programmable capabilities or the ability to store alphanumeric information. Print your name above, provide your UIN number, and sign the honor code statement below.

On my honor as an Aggie, I will neither give nor receive unauthorized assistance on this exam.

SIGNATURE: ______________________________
(1) (20 points, 2 pts each blank) Fill in the blanks. (Please enter just one word or chemical formula in each blank. You may use line the same word more than once if appropriate.

(a) An atom can be described as a collection of negatively charged ___________ moving around a small, dense, and positively charged __________ nucleus. 

(b) When a chemical equation is properly balanced, the number of __________ atoms on each side of the equation must be equal.

(c) The molarity of a solution is defined as the number of __________ moles of solute per ______________ of solution.

(d) A(n) ___________ of a solution that does not conduct electricity, that substance is called a(n) ___________ nonelectrolyte.

(g) Because acetic acid is only partially dissociated in solution, it is known as a(n) ___________ acid.

(h) Any substance that produces OH⁻ ions when dissolved in water is called a(n) ___________ base.

(2) (12 pts, 3 pts each) Consider two samples of liquid: one mole of water (H₂O) and one mole of ethanol (C₂H₅OH). The density of water is 1.0 g/mL, and the density of ethanol is 0.785 g/mL. Answer each of the following questions by circling your choice. (Note that most of these questions should require little or no calculation, so try to think before you start to churn numbers.)

(a) Which sample contains more molecules?
- the water  the ethanol  both the same

(b) Which sample contains more atoms?
- the water  the ethanol  both the same

(c) Which sample has a larger mass?
- the water  the ethanol  both the same

(d) Which sample has a larger volume?
- the water  the ethanol  both the same
(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>Compound</th>
<th>sa</th>
<th>wb</th>
<th>sb</th>
<th>s</th>
<th>wa</th>
</tr>
</thead>
<tbody>
<tr>
<td>HCl</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>CH₃NH₂</td>
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<tr>
<td>Ba(OH)₂</td>
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<tr>
<td>LiCl</td>
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</tr>
<tr>
<td>CH₃COOH</td>
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</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) (9 points) Ethyl propionate contains only carbon, hydrogen and oxygen. It has a pineapple-like odor and is found in small amounts in fruits like strawberries and kiwis. It imparts ice cream with a rum-like flavor. Complete combustion of a 50.0 g sample of ethyl propionate produced 107.7 g CO₂ and 44.07 g H₂O. If the molar mass of ethyl propionate is less than 120 g/mol, what is the molecular formula of ethyl propionate?

\[
50.0 \text{ g } \text{C}_x\text{H}_y\text{O}_z + \text{excess } \text{O}_2 \rightarrow 107.7 \text{ g } \text{CO}_2 + 44.07 \text{ g } \text{H}_2\text{O}
\]

\[
\frac{107.7 \text{ g } \text{CO}_2}{44 \text{ g/mol } \text{CO}_2} = 2.45 \text{ mol } \text{CO}_2 \quad (~2.45 \text{ mol C atoms, mass } = 29.41 \text{ g C})
\]

\[
\frac{44.07 \text{ g } \text{H}_2\text{O}}{18 \text{ g/mol } \text{H}_2\text{O}} = 2.45 \text{ mol } \text{H}_2\text{O} \quad (~4.90 \text{ mol H atoms, mass } = 4.90 \text{ g H})
\]

mass of oxygen = 50.0 – 29.41 – 4.90 = 15.7 g O; \[
\frac{15.7 \text{ g } \text{O}}{16 \text{ g/mol O}} = 0.98 \text{ mol O}
\]

\[
\text{C : H : O} = 2.45 : 4.90 : 0.98 = 5 : 10 : 2 \quad \therefore \text{empirical formula } = \text{C}_5\text{H}_{10}\text{O}_2
\]

That corresponds to a mass of 102 g/mol, so it is the molecular formula.

(6) (13 points) Shown below is the molecular structure of atrazine, a broadleaf herbicide that remains controversial because it breaks down very slowly in the environment and is the most commonly detected pesticide contaminant in drinking water. Though it remains approved for use in the US, it has been banned in the EU because of its long-lived contamination of groundwater.

![Molecular structure of atrazine](image)

Atrazine
(1-Chloro-3-ethylamino-5-isopropylamino-2,4,6-triazine)

(a) (5 pts) Give the molecular formula for atrazine.

\[\text{C}_8\text{H}_{14}\text{N}_3\text{Cl}\]

(b) (4 pts) Assuming your answer is correct; give the molar mass of atrazine to the nearest integer.

216 (215 gets 4 pts too)

(a) (4 pts) How many carbon atoms are there in 1.0 g of atrazine?

\[
(1 \text{ g})/(216 \text{ g/mol}) \times (6.0221 \times 10^{23} \text{ molecules/mol})(8 \text{ C atoms/molecule}) = 2.23 \times 10^{22} \text{ C atoms}
\]
(7) (8 points) As computer processor speeds increase, it is necessary for engineers to pack ever increasing numbers of circuit elements into a given area of a computer chip. Individual circuit elements are often connected using very small copper “wires” deposited directly on the surfaces of the chip. In current-generation processors, these copper interconnects are about 22 nm wide. How many copper atoms would be in a 1-mm length of such an interconnect, assuming a square cross section? (See the drawing, which is not to scale. The density of copper is 8.96 g/cm$^3$.)

$$\text{Volume} = (2.2 \times 10^{-6} \text{ cm})^2(1.00 \times 10^{-1} \text{ cm}) = 4.84 \times 10^{-13} \text{ cm}^3$$

$$\text{Mass of the copper} = (8.96 \text{ g/cm}^3)(4.84 \times 10^{-13} \text{ cm}^3) = 4.337 \times 10^{-12} \text{ g}$$

$$\text{Moles of copper} = \frac{4.337 \times 10^{-12} \text{ g}}{63.55 \text{ g/mol}} = 6.824 \times 10^{-14} \text{ mol}$$

$$\text{# of Cu atoms} = (6.824 \times 10^{-14} \text{ mol})(6.0221 \times 10^{23} \text{ atoms/mol}) = 4.11 \times 10^{10} \text{ atoms}$$

(8) (8 points) Seawater contains significant amounts of uranium in the form of aqueous uranyl, UO$_2^{2+}$, ions. The average UO$_2^{2+}$ content of the oceans has been estimated as $3.9 \times 10^{-3}$ mg UO$_2^{2+}$ 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 (U$_3$O$_8$) is currently $37.50 per lb. Based on the cost of U$_3$O$_8$, estimate the total dollar value of all of the uranium dissolved in the oceans.

$$1 \text{ gallon} = 3.7854 \text{ L} \quad 1 \text{ lb} = 454 \text{ g}$$

$$(3.5 \times 10^{20} \text{ gallons})(3.7854 \text{ L/gal}) = 1.325 \times 10^{21} \text{ L seawater}$$

$$\times 1.03 \text{ kg/L} = 1.365 \times 10^{21} \text{ kg seawater}$$

price of U$_3$O$_8$ is ($37.50 /lb)(1000 \text{ g/kg})(1/454 \text{ g}) = 82.60 /kg

$$3.9 \times 10^{-3} \text{ mg UO}_2^{2+} / \text{kg seawater} = 3.9 \times 10^{-9} \text{ kg UO}_2^{2+} / \text{kg seawater}$$

$$\text{(1.365 } \times 10^{21} \text{ kg seawater})(3.9 \times 10^{-9} \text{ kg UO}_2^{2+} / \text{kg seawater}) = 5.32 \times 10^{12} \text{ kg UO}_2^{2+} \text{ in the oceans}$$

mass of UO$_2^{2+}$ = 270 g/mol , mass of U$_3$O$_8$ = 842 g/mol (has 3 mol U per mole of U$_3$O$_8$)

$$270 \text{ g of UO}_2^{2+} \text{ gives } (842 \text{ g})/3 = 280.67 \text{ g of U}_3\text{O}_8$$

Therefore $5.32 \times 10^{12} \text{ kg UO}_2^{2+} \text{ gives } (280.67/270)(5.32 \times 10^{12} \text{ kg}) = 5.53 \times 10^{12} \text{ kg U}_3\text{O}_8$

Total dollar value = $(5.53 \times 10^{12} \text{ kg U}_3\text{O}_8)(82.60 /kg) = 4.57 \times 10^{14} \text{ dollars}$
(9) **(12 points)** There are many isotopes of uranium, but only two are present in greater than trace quantities on earth: $^{235}\text{U}$ and $^{238}\text{U}$. The data in the table below given can be used to calculate the molar mass of uranium, which is 238.0289 g/mol. The molar mass of uranium on earth hasn’t always had this value, however, because both of these isotopes have been very slowly decaying since the earth was formed about 4.5 billion years ago. The % abundances of the two isotopes have therefore changed since the earth was formed. Measurements of the rates of decay of the two isotopes allow us to calculate the how much of each isotope has decayed: **50.25% of the $^{238}\text{U}$ and 98.81% of the $^{235}\text{U}$ that were present 4.5 billion years ago have decayed.**

<table>
<thead>
<tr>
<th>Isotope</th>
<th>Isotopic Molar Mass (g/mol)</th>
<th>Current Abundance (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^{235}\text{U}$</td>
<td>235.043993</td>
<td>0.727</td>
</tr>
<tr>
<td>$^{238}\text{U}$</td>
<td>238.050788</td>
<td>99.273</td>
</tr>
</tbody>
</table>

Compute the molar mass of uranium on earth 4.5 billion years ago.

If today you have 0.727 mol of $^{235}\text{U}$, 4.5 billion years ago you would have had

$$\left(0.727 \text{ mol}\right) \left(\frac{100\%}{100\% - 98.81\%}\right) = 61.09 \text{ mol}$$

If today you have 99.273 mol of $^{238}\text{U}$, 4.5 billion years ago you would have had

$$\left(99.273 \text{ mol}\right) \left(\frac{100\%}{100\% - 50.25\%}\right) = 199.54 \text{ mol}$$

The abundances 4.5 billion years ago were

$^{235}\text{U}: \left(\frac{61.09}{61.09 + 199.54}\right) = 0.2344 \text{ (23.44\%)}$  
$^{238}\text{U}: \left(\frac{199.54}{61.09 + 199.54}\right) = 0.7656 \text{ (76.56\%)}$

Molar mass 4.5 billion years ago = $(235.043993)(0.2344) + (238.050788)(0.7656) = 237.35 \text{ g/mol}$
**PRACTICAL WORK**

**Name:**

**Physic constant/Conversion Factors**

<table>
<thead>
<tr>
<th>Name</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass of H₂O</td>
<td>1.0079 g/mmol</td>
</tr>
<tr>
<td>Mass of H₂</td>
<td>1.0081 g/mmol</td>
</tr>
<tr>
<td>Mass of O₂</td>
<td>0.032 atm, 1L/mol</td>
</tr>
<tr>
<td>Molar mass of H₂</td>
<td>2.016 g/mol</td>
</tr>
<tr>
<td>Molar mass of O₂</td>
<td>32.00 g/mol</td>
</tr>
<tr>
<td>Standard Temp.</td>
<td>0°C</td>
</tr>
<tr>
<td>Standard Pressure</td>
<td>1 atm</td>
</tr>
<tr>
<td>Avogadro's Number</td>
<td>6.0221 x 10^23</td>
</tr>
<tr>
<td>Faraday's Constant</td>
<td>96485 C/mol·V</td>
</tr>
</tbody>
</table>

**Physical Constants**

- **Speed of light**: 2.9979 x 10^8 m/s
- **Electron charge**: 1.6022 x 10^-19 C
- **Gay-Lussac's Law**: \( V \propto \frac{PV}{T} \)
- **Boyle's Law**: \( PV = k \)
- **Charles's Law**: \( V = \frac{k}{T} \)
- **Avogadro's Law**: \( V = k \)