This exam has 33 questions worth 5 pts each, plus one question worth 3 pts. The total possible score is 168 pts.

DO NOT OPEN THIS EXAM UNTIL TOLD TO DO SO

Before the exam begins you can do the following on the Scantron answer sheet. Use a #2 pencil.

1. Fill in your name (LAST NAME, FIRST NAME) in the large box on the left. Don't forget to bubble in the circles below your name.

2. Fill in your student ID number in the box labeled "IDENTIFICATION NUMBER". Do not use dashes or blank spaces. Fill in the circles as well.

3. In the box labelled "CLASS SECTION NUMBER", enter the appropriate number
   8 am class = section 001  9 am class = section 002  10 am class = section 003
   11am class = section 004  12pm class = section 005

4. In the lower right corner, in the box labelled "FORM NUMBER", write in the exam version number (1, 2, 3, 4 etc.) given above in the shaded box and fill in the bubble.

ONLY ONE APPROVED NOTECARD IS ALLOWED

ALL PHONES AND OTHER ELECTRONIC DEVICES OTHER THAN CALCULATORS MUST BE OFF

You may keep this exam packet and your notecard when the exam period is complete.

Hand in the Scantron answer sheet to a TA at the end of the exam.
"The 9 Polyatomic Ions"

<table>
<thead>
<tr>
<th>Name</th>
<th>Formula</th>
<th>Name</th>
<th>Formula</th>
<th>Name</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydroxide</td>
<td>OH⁻</td>
<td>Acetate</td>
<td>CH₃COO⁻</td>
<td>Hydronium</td>
<td>H₃O⁺</td>
</tr>
<tr>
<td>Cyanide</td>
<td>CN⁻</td>
<td>Carbonate</td>
<td>CO₃²⁻</td>
<td>Ammonium</td>
<td>NH₄⁺</td>
</tr>
<tr>
<td>Nitrate</td>
<td>NO₃⁻</td>
<td>Phosphate</td>
<td>PO₄⁴⁻</td>
<td>Sulfate</td>
<td>SO₄²⁻</td>
</tr>
</tbody>
</table>

**Densities of Some Materials**

<table>
<thead>
<tr>
<th>Element</th>
<th>Density (g/cm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cu (s)</td>
<td>8.94</td>
</tr>
<tr>
<td>Mg (s)</td>
<td>1.74</td>
</tr>
<tr>
<td>Al (s)</td>
<td>2.70</td>
</tr>
<tr>
<td>Fe (s)</td>
<td>7.87</td>
</tr>
<tr>
<td>Zn (s)</td>
<td>7.14</td>
</tr>
<tr>
<td>Ti</td>
<td>4.51</td>
</tr>
</tbody>
</table>

**ΔH°ₚ (kJ/mol)**

- CO₂ (g)  - 393.5
- C₂H₈ (g) - 104.0
- H₂O (l)  - 285.9

**Average Bond Energies (kJ/mol)**

- H-H     436
- Si-H    323
- F-F     159
- Si-F    159

**Mass of an electron = 9.109x10⁻³¹ kg**

**Nₐ = 6.022 x 10²³**
1. Consider the following operation: \((45.07 \text{ m} \times 5.34310 \text{ m}) + 2.13 \text{ m}^2\). The correct answer with the proper number of significant figures is:

(A) None of the below
(B) 242.944 m²
(C) 242.94 m²
(D) 242.9 m²
(E) 243. m²

\[
\frac{45.07 \times 5.34310}{10} = 240.8135 \text{ m}^2
\]

\[
\frac{2.13}{10} = 0.213 \text{ m}^2
\]

\[
240.8 + 0.213 = 242.93 \text{ m}^2
\]

2. What are the proper names of \(\text{P}_4\text{S}_3\) and \(\text{Ca}_3(\text{PO}_4)_2\)?

(A) tetraphosphorus trisulfide and tricalcium diphosphate
(B) phosphorus sulfide and calcium phosphate
(C) phosphorus sulfide and tricalcium diphosphate
(D) tetraphosphorus trisulfide and tricalcium di(phosphorus tetroxide)
(E) tetraphosphorus trisulfide and calcium phosphate

3. \(^{235}\text{U}^{2+}\) has:

(A) 92 protons, 143 neutrons, 90 electrons
(B) 235 protons, 235 neutrons, 235 electrons
(C) 235 protons, 235 neutrons, 237 electrons
(D) 92 protons, 146 neutrons, 90 electrons
(E) 92 protons, 92 neutrons, 94 electrons

\[
235 - 92 = 143
\]

4. Determine the mass percent composition of \(\text{CaSO}_4\).

(A) 16.7% Ca 16.7% S 66.7% O
(B) 20.0% Ca 20.0% S 60.0% O
(C) 25.1% Ca 20.5% S 54.4% O
(D) 29.4% Ca 23.6% S 47.0% O
(E) 33.3% Ca 33.3% S 33.3% O

\[
\text{CaSO}_4
\]

\[
\text{Ca} = \frac{40.08 \text{ g/mol}}{136.14 \text{ g/mol}} \times 100\% = 29.4\% \text{ Ca}
\]

\[
\text{S} = \frac{32.06 \text{ g/mol}}{136.14 \text{ g/mol}} \times 100\% = 23.6\% \text{ S}
\]

\[
\text{O} = \frac{(4)16.00 \text{ g/mol}}{136.14 \text{ g/mol}} \times 100\% = 47.0\% \text{ O}
\]

\[
100\%
\]
5. Upon combustion in excess oxygen, 2.447 grams of a compound containing only carbon, hydrogen, and oxygen produces 4.246 grams of CO₂ (g) and 2.318 grams of H₂O (g). What is the empirical formula of the compound?

(A) C₄H₈O  
(B) C₃H₇O₂  
(C) C₃H₈O  
(D) C₃H₈O₅  
(E) C₄H₈O₃  

\[
\text{C} \rightarrow 4.246 \text{ g CO}_2 \left( \frac{1 \text{ mol CO}_2}{44.01 \text{ g CO}_2} \right) = 0.0965 \text{ mol C} \left( \frac{12.011 \text{ g C}}{1 \text{ mol C}} \right) \approx 1.159 \text{ g C}
\]

\[
\text{H} \rightarrow 2.318 \text{ g H}_2\text{O} \left( \frac{1 \text{ mol H}_2\text{O}}{18.02 \text{ g H}_2\text{O}} \right) \left( \frac{2 \text{ mol H}}{1 \text{ mol H}_2\text{O}} \right) = 0.2573 \text{ mol H} \left( \frac{1.0079 \text{ g H}}{1 \text{ mol H}} \right) = 0.2593 \text{ g H}
\]

\[
\text{O} \rightarrow 2.447 \text{ g CHO compound} - 1.159 \text{ g C} - 0.2593 \text{ g H} = 1.0287 \text{ g O}
\]

\[
1.0287 \text{ g O} \left( \frac{1 \text{ mol O}}{16.00 \text{ g O}} \right) = 0.0643 \text{ mol O}
\]

\[
\text{C} \quad \text{H} \quad \text{O}
\]

\[
\frac{0.0965 \text{ mol O}}{0.0643 \text{ mol O}} \quad \frac{0.2593 \text{ mol O}}{0.0643 \text{ mol O}} \quad \frac{0.0643 \text{ mol O}}{0.0643 \text{ mol O}}
\]

\[
\text{C}_{1.5} \quad \text{H}_4 \quad \text{O}_3 \quad \text{or} \quad \text{C}_3\text{H}_8\text{O}_2
\]

6. Which of the following statements is TRUE?

(A) A scientific law is fact. True
(B) Once a theory is constructed, it is considered fact. False
(C) A hypothesis is speculation that is difficult to test. False
(D) An observation explains why nature does something. False
(E) A scientific law summarizes a series of related observations. True

7. A student obtains a cube of copper with a side measuring 2.37 inches. How many electrons are present in the sample? [Possibly useful information is located on the cover pages]

\[
\text{(A) } 5.81 \times 10^{25} \text{ electrons}
\]

\[
\text{(B) } 9.54 \times 10^{25} \text{ electrons}
\]

\[
\text{(C) } 4.46 \times 10^{25} \text{ electrons}
\]

\[
\text{(D) } 2.23 \times 10^{25} \text{ electrons}
\]

\[
\text{(E) } 5.36 \times 10^{26} \text{ electrons}
\]

\[
\text{Volume of cube } = (2.37 \text{ in})^3 = 2.37 \text{ in} \times 2.37 \text{ in} \times 2.37 \text{ in} = 21.8 \text{ cm}^3
\]

\[
\left( \frac{6.02 \times 10^{23} \text{ atoms}}{1 \text{ mol Cu}} \right) = 1.847 \times 10^{25} \text{ Cu atoms}
\]

\[
1.847 \times 10^{25} \text{ Cu atoms} \left( \frac{29 \text{ e}^-}{1 \text{ Cu atom}} \right) = 5.36 \times 10^{26} \text{ e}^-
\]

\[
1.847 \times 10^{25} \text{ Cu atoms} \left( \frac{63.546 \text{ g Cu}}{1 \text{ mol Cu}} \right) = 30.67 \text{ mol Cu}
\]

\[
30.67 \text{ mol Cu} \left( \frac{6.022 \times 10^{23} \text{ Cu atoms}}{1 \text{ mol Cu}} \right) = 1.847 \times 10^{25} \text{ Cu atoms}
\]
8. A fictitious element, Knutsonium, has two naturally occurring isotopes, $^{285}$Kn (284.67 g/mol) and $^{288}$Kn (287.73 g/mol). The average atomic mass of Knutsonium is 286.85 g/mol. What is the percent abundance of $^{285}$Kn?

(A) 50.00%
(B) 28.76%
(C) 23.93%
(D) 34.44%
(E) 68.88%

9. When the reaction

$$\text{C}_{17}\text{H}_{36} (l) + 26 \text{ O}_2 (g) \rightarrow 17 \text{ CO}_2 (g) + 18 \text{ H}_2\text{O} (g)$$

is correctly balanced, how many oxygen atoms are there?

(A) 17 O$_2$ are consumed.
(B) 18 O$_2$ are consumed.
(C) 19 O$_2$ are consumed.
(D) 23 O$_2$ are consumed.
(E) 26 O$_2$ are consumed.

10. Which functional group is NOT in the molecule depicted below?

![Molecule Diagram]

(A) An alcohol
(B) An aldehyde
(C) A ketone
(D) A carboxylic acid
11. How many O₂ molecules are needed to turn 72.06 g of C<sub>graphite</sub> into CO?

(A) \[1.807 \times 10^{24}\] molecules
(B) \[2.606 \times 10^{26}\] molecules
(C) \[7.226 \times 10^{24}\] molecules
(D) \[9.963 \times 10^{24}\] molecules
(E) \[7.746 \times 10^{23}\] molecules

\[
\begin{align*}
C(\text{graphite}) + \frac{1}{2} O_2(g) &\rightarrow CO(g) \\
\text{C (\text{graphite})} &\rightarrow \frac{1}{2} \text{O}_2(g) \\
72.06 \text{ g} &\rightarrow 1.807 \times 10^{24} \text{ molecules} \\
6.00 \text{ mol} &\rightarrow 3.00 \text{ mol O}_2 \\
3.00 \text{ mol O}_2 &\rightarrow 1.807 \times 10^{24} \text{ O}_2 \text{ molecules}
\end{align*}
\]

12. Which of the following statements is **FALSE**?

(A) Halogens (Group VII) are very reactive elements. **True**
(B) The alkali metals (Group I) are fairly unreactive. **False! Na, K, ... are very reactive**
(C) Sulfur is a main group element. **True**
(D) Noble gases do not usually form ions. **True**
(E) Zn is a transition metal. **True**

13. Determine ΔH° for this reaction:

\[2 \text{ N}_2(g) + 5 \text{ O}_2(g) \rightarrow 2 \text{ N}_2\text{O}_5(g)\]

using the following three equations:

\[
\begin{align*}
\text{(1) } &\text{ H}_2(g) + \frac{1}{2} \text{ O}_2(g) \rightarrow \text{ H}_2\text{O}(l) & &\Delta H_1^\circ = -285.8 \text{ kJ} \\
\text{(2) } &\text{ N}_2\text{O}_5(g) + \text{ H}_2\text{O}(l) \rightarrow 2\text{ HNO}_3(l) & &\Delta H_2^\circ = -76.6 \text{ kJ} \\
\text{(3) } &\text{ 2 N}_2(g) + 6 \text{ O}_2(g) + 2 \text{ H}_2(g) \rightarrow 4 \text{ HNO}_3(l) & &\Delta H_3^\circ = -696.4 \text{ kJ} \\
\end{align*}
\]

\[
\begin{align*}
\text{\textbf{Equation 1} } &\text{ 2 H}_2\text{O}(l) \rightarrow 2 \text{ H}_2(g) + \frac{1}{2} \text{ O}_2(g) & &\Delta H_1^\circ = (-285.8 \text{ kJ})(-2) \\
\text{\textbf{Equation 2} } &\text{ 4 HNO}_3(l) \rightarrow 2 \text{ N}_2\text{O}_5(g) + 2 \text{ H}_2\text{O}(l) & &\Delta H_2^\circ = (-76.6 \text{ kJ})(2) \\
\text{\textbf{Equation 3} } &\text{ 2 N}_2(g) + 5 \text{ O}_2(g) + 2 \text{ H}_2(g) \rightarrow 4 \text{ HNO}_3(l) & &\Delta H_3^\circ = (-696.4 \text{ kJ})
\end{align*}
\]

\[
\begin{align*}
\text{\textbf{Total}} &\text{ 2 N}_2(g) + 5 \text{ O}_2(g) \rightarrow 2 \text{ N}_2\text{O}_5(g) & &\Delta H_{\text{rxn}}^\circ = +28.4 \text{ kJ}
\end{align*}
\]

(A) -95.8 kJ
(B) +371 kJ
(C) **+28.4 kJ**
(D) -1059 kJ
(E) +1345 kJ
14. A student places 340.0 grams of Au (s) at 94.5 °C into 100.0 grams of H₂O (l) at 18.0 °C. What is the final temperature of the Au (s) and H₂O (l)?

(A) 18.0 °C  
(B) 38.3 °C  
(C) 19.9 °C  
(D) 25.2 °C  
(E) 29.9 °C

\[ q_{Au} = -q_{H₂O} \]
\[ m_{Au} c_{Au} \Delta T_{Au} = -m_{H₂O} c_{H₂O} \Delta T_{H₂O} \]
\[ (340.0 \times 0.128 \text{ J/°C})(T_f - 94.5°C) = -(100.0 \times 4.184 \text{ J/°C})(T_f - 18.0°C) \]

\[ 461.92 \text{ J/°C} T_f = 4113 J = -418.4 \text{ J/°C} T_f + 7531 J \]

\[ T_f = 25.2°C \]

15. When the following reaction is carried out in a flask, the flask feels COLD when held in the hands:

\[ \text{NH₄NO₃ (s)} \rightarrow \text{NH₄NO₃ (aq)} \quad \text{[This reaction is the system]} \]
Which of the following is TRUE?

(A) Heat is transferred from the flask to the hand; this is an endothermic reaction.  
(B) Heat is transferred from the flask to the hand; this is an exothermic reaction.  
(C) Heat is transferred from the hand to the flask; this is an endothermic reaction.  
(D) Heat is transferred from the hand to the flask; this is an exothermic reaction.

16. The energy of two moles of blue photons having a wavelength of 480 nm is:

(A) 498 kJ  
(B) 568 kJ  
(C) 604 kJ  
(D) 1208 kJ  
(E) 1812 kJ

\[ J = \frac{c}{\lambda} = \frac{3.00 \times 10^8 \text{ m/s}}{480 \times 10^{-9} \text{ m}} = 6.25 \times 10^{14} \text{ J} \]

\[ E = hJ = \left(6.626 \times 10^{-34} \text{ J s/ photon}\right) \left(6.25 \times 10^{14} \text{ J} \right) = 4.14 \times 10^{-19} \text{ J/ photon} \]

\[ \frac{4.14 \times 10^{-19} \text{ J/ photon}}{\text{1 mol photons}} \times \frac{6.022 \times 10^{23} \text{ photons}}{\text{1 mol}} = 249,000 \text{ J/mol} \text{ or } 249 \text{ kJ/mol} \]

\[ 2 \text{ mol} \left(\frac{249 \text{ kJ/mol}}{\text{mol}}\right) = 498 \text{ kJ} \]
17. Consider the Bohr Model for the Hydrogen Atom. Which of the following electron transitions releases electromagnetic radiation with the **longest** wavelength?

(A) \( n = 7 \) to \( n = 6 \)
(B) \( n = 2 \) to \( n = 1 \)
(C) \( n = 1 \) to \( n = 2 \)
(D) \( n = 5 \) to \( n = 4 \)
(E) \( n = 3 \) to \( n = 4 \)

18. Which of the following statements is **false**?

(A) The frequency of blue light is greater than the frequency of red light.  **True**
(B) The wavelength of blue light is greater than the wavelength of red light.  **False**
(C) Both blue and red light are in the visible region of the electromagnetic spectrum.  **True**
(D) One mole of blue photons has a greater energy than one mole of red photons.  **True**
(E) Blue and red light travel at the same speed in a vacuum.  **True**

19. Which set of four quantum numbers describes an electron in the orbital pictured below?

(A) \( n = 1, l = 0, m_l = 0, m_s = +\frac{1}{2} \)
(B) \( n = 1, l = 1, m_l = 0, m_s = +\frac{1}{2} \)  **bad set... when \( n = 1, \ell \text{ must be} 0 \)**
(C) \( n = 2, l = 1, m_l = 0, m_s = +\frac{1}{2} \)
(D) \( n = 2, l = 2, m_l = 0, m_s = +\frac{1}{2} \)
(E) \( n = 3, l = 2, m_l = 1, m_s = +\frac{1}{2} \)
20. Which of the following statements is TRUE?

(A) The emission spectrum of a particular element is always the same and can be used to identify the element.  True
(B) Part of the Bohr model proposed that electrons in the hydrogen atom are located in "stationary states" or particular orbits around the nucleus.  True
(C) The uncertainty principle states that we can never know both the exact location and speed of an electron.  True
(D) An orbital is the volume in which we are most likely to find an electron.  True
(E) All of the above are true.

21. The electron configuration 1s\(^2\)2s\(^2\)2p\(^6\)3s\(^2\)3p\(^6\)4s\(^2\)3d\(^{10}\) depicts: 30e\(^-\)

(A) Ge
(B) Zn
(C) Ni
(D) Ar
(E) Kr

22. Consider K, Mg, Si, N, and O. The atom with the largest atomic size is:

(A) K
(B) Mg
(C) Si
(D) N
(E) O

23. Consider Li, Li\(^+\), F, and F\(^-\). Which of the following statements is correct?

(A) Li is larger than Li\(^+\).  Li\(^+\) has one fewer e\(^-\), but the same number of protons.
(B) F is larger than F\(^-\).
(C) Li\(^+\) is larger than F\(^-\).
(D) Li is smaller than F.
(E) All of the above are true.
24. Consider C₂H₆, C₂H₄, and C₂H₂. Which of these has the shortest carbon-carbon bond? [It may be helpful to draw Lewis Structures]

(A) C₂H₆
(B) C₂H₄
(C) C₂H₂

25. The Lewis Dot Structure of phosphine, PH₃, depicts:

(A) There are no lone pairs of electrons.
(B) **There is one lone pair of electrons.**
(C) There are two lone pairs of electrons.
(D) There are three lone pairs of electrons.
(E) There are four lone pairs of electrons.

26. The Lewis Dot Structure of SF₆ depicts there are ____ bonding pairs of electrons and ____ lone pairs of electrons about the central sulfur atom.

(A) **6, 0**
(B) 4, 0
(C) 4, 4
(D) 0, 4
(E) 4, 2
27. Which of the following is the Lewis Structure of Se?

(A) \[
\begin{array}{c}
\text{Se} \\
\cdot \\
\end{array}
\]

(B) \[
\text{Se} \\
\cdot \\
\end{array}
\]

(C) \[
\text{Se} \\
\cdot \\
\end{array}
\]

(D) \[
\begin{array}{c}
\text{Se} \\
\cdot \\
\end{array}
\]

(E) \[
\begin{array}{c}
\cdot \\
\end{array}
\]

28. A student \( \text{\`A} \) proposes the following two Lewis Dot Structures, shown below, for the cyanate ion, [OCN]. By calculating the formal charges on the atoms in both structures and considering the electronegativity of Oxygen and Nitrogen determine which structure is the more likely representation of the cyanate ion.

\[
\begin{array}{c}
\text{O} \\
\cdot \\
\end{array}
\begin{array}{c}
\text{C} \\
\cdot \\
\end{array}
\begin{array}{c}
\text{N} \quad 4-4=0 \\
\cdot \\
\end{array}
\]

\[6-7=-1 \quad 5-5=0\]

Structure 1

\[
\begin{array}{c}
\text{O} \\
\cdot \\
\end{array}
\begin{array}{c}
\text{C} \\
\cdot \\
\end{array}
\begin{array}{c}
\text{N} \quad 4-4=0 \\
\cdot \\
\end{array}
\]

\[6-5=+1 \quad 5-7=-2\]

Structure 2

(A) Structure 1 is the more likely configuration.
(B) Structure 2 is the more likely configuration.
(C) Both structures are equally likely.
29. How many valence electrons are present in F?

(A) 8  
(B) 6  
(C) 7  
(D) 5  
(E) 9

30. There are 3 resonance forms for the nitrate ion (NO₃⁻).

(A) 0  
(B) 1  
(C) 2  
(D) 3  
(E) 4

31. Which compound contains the most polar covalent bond?

(A) HF  
(B) H₂O  
(C) NH₃  
(D) CH₄  
(E) F₂
32. Consider the 1st ionization energy of Mg. Which of the following equations **CORRECTLY** represents the 1st ionization of Mg?

(A) \( \text{Mg} \rightarrow \text{Mg}^+ + \text{e}^- \quad \Delta H > 0 \)

(B) \( \text{Mg} \rightarrow \text{Mg}^+ + \text{e}^- \quad \Delta H < 0 \)

(C) \( \text{Mg} + \text{e}^- \rightarrow \text{Mg}^- \quad \Delta H > 0 \)

(D) \( \text{Mg} \rightarrow \text{Mg}^{2+} + 2\text{e}^- \quad \Delta H < 0 \)

(E) \( \text{Mg} \rightarrow \text{Mg}^{2+} + 2\text{e}^- \quad \Delta H > 0 \)

Looking for the removal of an e\(-\) and an endothermic process (\( \Delta H > 0 \)).

33. Co\(^{2+}\) is:

(A) diamagnetic
(B) **paramagnetic**
(C) trimagnetic
(D) ultramagnetic
(E) ladygagamagnetic

\( 27 - 2 = 25 \text{e}^- \)
Questions 1 through 33 each have 5 points attached. Any response to Question 34 will receive full credit (3 Points); even no response.

The point total for this exam is 168 points. See the grade sheet or CH 221 web syllabus for grade computation details.

Final exam keys, scores, and course grades will be posted on the CH 221 website as they become available.

Have an excellent and safe Winter Break 😊