This exam has 200 points total.

**Part I. Short Answer.** Answer 12 of the next 13 questions. You MUST cross out the one you wish not to be graded. 5 points each.

<table>
<thead>
<tr>
<th></th>
<th>Name</th>
<th>Chemical Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>1a.</td>
<td></td>
<td>NF₃</td>
</tr>
<tr>
<td>1b.</td>
<td>Calcium carbonate</td>
<td></td>
</tr>
<tr>
<td>2a.</td>
<td></td>
<td>NH₄Br</td>
</tr>
<tr>
<td>2b.</td>
<td>Magnesium sulfate heptahydrate</td>
<td></td>
</tr>
</tbody>
</table>

3. Magnesium has 3 stable isotopes. What is the isotopic abundance of $^{24}\text{Mg}$?

<table>
<thead>
<tr>
<th>Isotope</th>
<th>Mass</th>
<th>Isotopic Abundance</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^{24}\text{Mg}$</td>
<td>23.98504 amu</td>
<td>?</td>
</tr>
<tr>
<td>$^{25}\text{Mg}$</td>
<td>24.98583 amu</td>
<td>10.00 %</td>
</tr>
<tr>
<td>$^{26}\text{Mg}$</td>
<td>25.98259 amu</td>
<td>11.01%</td>
</tr>
</tbody>
</table>

Isotopic abundance of $^{24}\text{Mg}$: ________%

What is the atomic weight of Magnesium (show your work)?

__________ g/mol

4. How many moles of PbO are produced from the reaction of 5.0 mol of PbS and 6.0 mol of $\text{O}_2$?

$$2 \text{ PbS (s) + 3 O}_2 (g) \rightarrow 2 \text{ PbO (s) + 2 SO}_2 (g)$$

__________ moles PbO
5. What is the oxidation number of each element in NaBiO₃?

Na: _______  Bi: _______  O: _______

6. True or False:
   _____ A. When chemical bonds are broken, energy is released.
   _____ B. The phase change of liquid to solid, commonly called freezing, is exothermic.
   _____ C. The electrons in a molecule can be in an excited state if the molecule absorbed a photon.
   _____ D. If a substance absorbs red photons, it will appear red.
   _____ E. Heat (q) and work (w) are two examples of state functions.

7. Rank the following atoms or ions:
   A. Increasing ATOMIC radius: O, F, Ga, Br
      _______ < _______ < _______ < _______
   B. Increasing IONIC radius: Ti⁴⁺, V⁵⁺, Cl⁻
      _______ < _______ < _______
   C. Increasing SECOND Ionization Energy: K, Ca, Sc
      _______ < _______ < _______

8. Which of the following molecules have dipole-dipole interactions as an intermolecular force? Circle all correct answers.

A) ICl₄⁻
B) PCl₅
C) ClF₃
D) SO₂
E) None of the above
9. Which of the following molecules has the molecular geometry known as T-Shaped? Circle all correct answers.

A) ClO$_3^-$  
B) ClF$_3$  
C) NF$_3$  
D) IF$_3$  
E) None of the above

10. How many total, angular, and radial nodes does a 4d orbital have?
Total nodes: _________  Angular nodes: _________  Radial nodes: ______________

11. Which atom or ion has exactly 3 unpaired electrons? Circle all correct answers.

A) Cr$^{3+}$  
B) P$^+$  
C) Sc  
D) V$^{2+}$

12. Adding the following compounds to water will increase the boiling point and decrease the freezing point. Assuming one mole of each is added to water, rank the compounds in terms of boiling point elevation (1 = highest to 3 = lowest)

___________ NaCl, ___________ MgCl$_2$, ______________ CH$_3$CH$_2$OH

13. Indicate if the following combinations will form a stable solution. Fill in the blank with the appropriate key term: soluble, insoluble, miscible, or immiscible.

___________ Pb(NO$_3$)$_2$ (s) in H$_2$O (l)  
___________ CH$_3$OH (l) in NH$_3$ (l)  
___________ NaCl (s) in CO$_2$ (l)
Part II. Problems. Answer 6 of the next 7 questions. You MUST cross out the one you wish not to be graded. 12 points each.

14. What is the \textbf{wavelength} of a photon that can excite an electron in a hydrogen atom from the 1s orbital to a 3d orbital? Report your answer in nanometers and with three significant digits.

15. What are the partial pressures of all gases when a 1.7 L ridged container of \( \text{N}_2\text{O}_5 \) at 0°C and 1.00 atm pressure decomposes completely into \( \text{NO}_2 \) (g) and \( \text{O}_2 \) (g)?

\textbf{Unbalanced} Reaction: \( \text{N}_2\text{O}_5 \rightarrow \text{NO}_2 + \text{O}_2 \)

\( P_{\text{N}_2\text{O}_5} \) \________________ \( P_{\text{NO}_2} \) \________________ \( P_{\text{O}_2} \) \________________

16. In each list:
A. Circle which molecule has \textbf{the highest boiling point}. Explain why.

\( \text{F}_2 \quad \text{Br}_2 \quad \text{Cl}_2 \)

Why? __________________________

B. Circle which molecule has \textbf{the highest vapor pressure}. Explain why.

\( \text{CH}_3\text{CH}_2\text{OH} \quad \text{CH}_3\text{COCH}_3 \quad \text{CH}_3\text{CH}_2\text{CH}_3 \)

Why? __________________________

C. Circle which atom or molecule is \textbf{diamagnetic}. Explain why.

\( \text{N}_2 \quad \text{O}_2 \quad \text{Al} \)

Why? __________________________
17. An unknown compound contains only carbon, nitrogen, and hydrogen (and no oxygen). When the unknown is combusted completely with excess oxygen it produces 55.0 g of CO₂, 15.8 g of H₂O, and 23.0 g of NO₂. What is the empirical formula of the compound?

18. When the following solutions are mixed together, what precipitate (if any) will form? If no precipitate forms, indicate that fact.
   
   A. Al(NO₃)₃ (aq) + Ba(OH)₂ (aq) \rightarrow 
   
   B. Na₂SO₄ (aq) + Pb(NO₃)₂ (aq) \rightarrow 
   
   C. KCl (aq) + NH₄Br (aq) \rightarrow 

19. What is the mass of Ca(OH)₂ (s) required to neutralize 12.0 mL of 3.50 M HClO₄ (aq)?

20. Given the following reactions,
   
   Fe₂O₃ (s) + 3CO (g) \rightarrow 2Fe (s) + 3CO₂ (g) \quad \Delta H = -28.0 \text{ kJ} 
   
   3Fe (s) + 4CO₂ (g) \rightarrow 4CO (g) + Fe₃O₄ (s) \quad \Delta H = +12.5 \text{ kJ} 

   What is the enthalpy of the reaction of Fe₂O₃ with CO?
   
   3 Fe₂O₃ (s) + CO (g) \rightarrow CO₂ (g) + 2 Fe₃O₄ (s)
Part III. **Problems.** Answer 4 of the next 5 questions. You MUST cross out the one you wish not to be graded. 17 points each.

21. A. Using Lewis structures and resonance structures, which molecule has a higher bond order, NO$_2^-$ or NO$_3$? 

   B. Using molecular orbital theory, which molecule has a higher bond order, NO or NO$^-$?  
   Draw the molecular orbital diagrams and indicate the electron filling. Hint: NO has a molecular orbital diagram similar to N$_2$. 

   C. Using molecular orbital theory, decide if OF is more likely to form an OF$^+$ ion or an OF$^-$ ion.  
   Draw the molecular orbital diagram and indicate the electron filling. Hint: OF has a molecular orbital diagram similar to O$_2$. 

22. A. How much heat (in kJ) is required to convert a 100. cm³ block of ice that has an initial temperature of -40.0°C into liquid water at 0.0 °C? (Data: ΔH_{fus} = 6.01 kJ/mole, density (ice)=0.9340 g/cm³, C_p (ice)= 2.1 J/g °C, C_p (water)= 4.2 J/g °C)

B. Using enthalpies of formation, would the combustion of 1.07 L of methane (g) at 1.00 atm of pressure and 25 °C provide enough heat to melt the 100. cm³ block of ice that starts at -40.0°C? Show your work.

<table>
<thead>
<tr>
<th>Substance</th>
<th>ΔH_\rho (kJ/mol)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH_4(g)</td>
<td>-75.0</td>
</tr>
<tr>
<td>H_2O (g)</td>
<td>-242</td>
</tr>
<tr>
<td>CO_2(g)</td>
<td>-393.5</td>
</tr>
</tbody>
</table>

C. Using bond enthalpies, would the combustion of 1.0 g of acetylene (HCCH) provide enough heat to melt the 100. cm³ block of ice that starts at -40.0°C? Show your work.

Hint: Acetylene is a linear molecule with one hydrogen attached to each carbon.

<table>
<thead>
<tr>
<th>Bond Type</th>
<th>C-H</th>
<th>C-C</th>
<th>O-H</th>
<th>C=O</th>
<th>C=C Double bond</th>
<th>C≡C Triple bond</th>
<th>O=O</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bond Enthalpy (kJ/mol)</td>
<td>413</td>
<td>348</td>
<td>463</td>
<td>799</td>
<td>614</td>
<td>839</td>
<td>495</td>
</tr>
</tbody>
</table>
23. Below is the phase diagram for N₂. The gray solid line at 1.0 atm is provided to help guide your eye.

A. Label the following 6 points on the graph. Label each region as either solid, liquid, gas, or super critical fluid. Label the triple point and the critical point.

B. What is the phase transition that happens at 1 atm of pressure as the temperature increases from -200 °C to 25 °C?

C. What is the minimum pressure necessary to create liquid N₂?

D. At 2.00 atm of pressure, which value is closest to the freezing temperature of N₂? Circle the best answer:

   a) -211 °C  b) -209 °C  c) -192 °C  d) -200 °C  e) -140 °C

E. Label the phase diagram with a star (*) at the pressure and temperature conditions of this room. Define the P and T at this point.
24. Balance the following redox reaction using the methods of half reactions. Show your work.
A. \( \text{NH}_3(g) + \text{O}_2(g) \rightarrow \text{NO}(g) + \text{H}_2\text{O}(g) \)

B. Which reactant has been oxidized?

C. Which reactant has been reduced?

D. If 3.49 g of ammonia and 2.16 g of oxygen are allowed to react, what volume of nitric oxide is evolved at 273.2 K and 1.00 atm?

25. A solution of 5.00 g of lauryl alcohol in 0.100 kg of benzene freezes at 4.1°C. Calculate the molar mass of lauryl alcohol. \( K_f \) for benzene is 5.12 °C kg/mol and the normal freezing point of benzene is 5.5°C. Show all work.