Instructions

1. Do not open the exam until you are told to start.

2. This exam is closed note and closed book. You are not allowed to use any outside material while taking this exam.

3. Use the spaces provided to write down your answers. To receive full credit, you must show all work. Do not write answers on any other pieces of paper. If you need more room, write on the back of the exam and be sure to include a note describing where the work is located.

4. When solving numerical problems, make sure you include the proper units in your final answer.

5. If a question asks for a response in sentence or paragraph form, make sure you respond in that format.

6. Useful data for the exam and a periodic table are provided on the last page of the exam. Carefully tear out these sheets if you wish.

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<th>Points awarded</th>
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Multiple Choice
Unless otherwise directed, choose the single best answer for each question. Some of the chemical equations will be balanced and some will not. Each question is worth three points.

1. Using the chemical equation below, calculate the number of moles of CuO that will be produced if 3.25 moles of O_2 react with excess Cu.

\[ 2 \text{Cu(s)} + \text{O}_2(g) \rightarrow 2 \text{CuO(s)} \]

a.) 3.25 mol CuO
b.) 1.63 mol CuO
c.) 9.75 mol CuO
d.) 6.50 mol CuO
e.) None of the above.

When methane is combusted, it reacts with O_2 and produces CO_2 and H_2O. The balanced chemical equation for this reaction is shown below. **Use this equation and the diagrams below to answer the following two questions.**

\[ \text{CH}_4(g) + 2\text{O}_2(g) \rightarrow \text{CO}_2(g) + 2\text{H}_2\text{O}(g) \]

![Before Reaction Diagram]

![After Reaction Diagram]

- ○ hydrogen
- ○ oxygen
- ● carbon

2. Which compound is the limiting reagent?

a.) CH_4
b.) O_2
c.) CO_2
d.) H_2O
e.) None of the above.

3. What is the total number of molecules in the container after the reaction is complete?

a.) 3
b.) 4
c.) 5
d.) 6
e.) 7

4. According to the balanced chemical equation shown below, what mass of S_8 is needed to react with 2.45 g of H_2?

\[ 8\text{H}_2(g) + 8\text{S}_8(s) \rightarrow 8\text{H}_2\text{S}(g) \]

Molar Mass (g/mole)

<table>
<thead>
<tr>
<th>S_8</th>
<th>H_2</th>
</tr>
</thead>
<tbody>
<tr>
<td>256.528</td>
<td>2.01588</td>
</tr>
<tr>
<td>34.081</td>
<td>2.45</td>
</tr>
</tbody>
</table>

a.) 39.0 g S_8
b.) 312 g S_8
c.) 2.49x10^3 g S_8
d.) 158 g S_8
e.) None of the above.
5. According to the balanced chemical equation shown below, if 13 g of C₂H₂ are produced during a reaction, how many grams of H₂O must have reacted?

\[
\text{CaC}_2(s) + 2\text{H}_2\text{O}(g) \rightarrow \text{Ca(OH)}_2(s) + \text{C}_2\text{H}_2(g)
\]

Molar Mass (g/mole) 
\[
\begin{array}{cccc}
64.100 & 18.0153 & 74.093 & 26.038 \\
\end{array}
\]

a.) 4.5 g H₂O  
b.) 9.0 g H₂O  
c.) 4.8x10² g H₂O  
d.) 18 g H₂O  
e.) None of the above.

6. A solution is made by dissolving 14.7 g of H₂SO₄ in enough water to make 2.00x10² mL of solution. What is the molarity of this H₂SO₄ solution?

a.) 1.33 M  
b.) 0.749 M  
c.) 0.770 M  
d.) 0.0735 M  
e.) None of the above.

7. The point in a titration at which the indicator changes color is called the end point. In an acid-base titration in which a base is the titrant, how does the volume of base required to reach the end point \((V_{\text{end point}})\) differ from the volume of base required to reach the equivalence point \((V_{\text{equivalence point}})\)?

a.) \(V_{\text{end point}} = V_{\text{equivalence point}}\)  
b.) \(V_{\text{end point}} > V_{\text{equivalence point}}\)  
c.) \(V_{\text{end point}} < V_{\text{equivalence point}}\)  
d.) None of the above.

8. A chemist adds 25.00 mL of deionized water to a beaker that already contains 100.0 mL of a 2.50 M NaCl solution. How many moles of NaCl are in the beaker?

a.) 0.250 moles of NaCl  
b.) 0.313 moles of NaCl  
c.) 25.0 moles of NaCl  
d.) 0.0625 moles of NaCl  
e.) None of the above
Shown below are energy level diagrams for arsenic (As), iron (Fe), and lithium (Li). In the diagrams, a valence electron is shown in the ground state right before the atoms are exposed to visible light. Once exposed to the light, each electron is promoted to an excited state. Use the diagrams to answer the following question.

9. If arsenic absorbed a photon of only blue light, iron absorbed a photon of only orange light, and lithium absorbed a photon of only red light, which diagram represents the energy level diagram for iron?

a.) Diagram 1.
b.) Diagram 2.
c.) Diagram 3.
d.) They could all represent arsenic.

10. A given set of d-orbitals consists of _____ orbitals?

a.) 1
b.) 3
c.) 5
d.) 7
e.) 10

11. How many unpaired electrons does the sulfur atom contain. Use the orbital box diagram for sulfur to help you answer this question.

a.) 1
b.) 2
c.) 3
d.) 6
e.) None of the above.

12. A 23.25 mL sample of 0.2560 M \( \text{H}_3\text{PO}_4(\text{aq}) \) is titrated with a 0.4900 M \( \text{NaOH(\text{aq})} \) solution. What volume of \( \text{NaOH(\text{aq})} \) is required to reach the equivalence point of the titration?

\[
\text{H}_3\text{PO}_4(\text{aq}) + 3\text{NaOH(\text{aq})} \rightarrow \text{Na}_3\text{PO}_4(\text{aq}) + 3\text{H}_2\text{O(l)}
\]

a.) 12.15 mL
b.) 36.44 mL
c.) 23.25 mL
d.) 4.049 mL
e.) None of the above.
13. Which of the elements below is the smallest?
Al, Ga, K, Ca

a.) Al  
d.) K
b.) Ga  
e.) Ca
c.) B

14. A 2.36 mole sample of K₃PO₄ is dissolved in enough water to make 325 mL of solution. What is the concentration of potassium ions in this solution?

\[ \frac{2.36 \text{ mol K}_3\text{PO}_4 \times 3 \text{ mol K}^+}{0.325 \text{ L}} = 21.7184 \text{ M K}^+ \]

\[ \text{K}^+ = 21.8 \text{ M} \]

a.) 7.26x10⁻³ M  
b.) 7.26 M  
c.) 21.8 M  
d.) 2.36 M  
e.) None of the above.

15. You have 100.0 mL of a 0.2500 M solution of NaCl sitting in a beaker. After several days you notice that water has evaporated and the volume has decreased. When you test the solution, you find that it is 0.3125 M NaCl. How much water must have evaporated?

\[ V = 100.0 \text{ mL} \]
\[ \text{[NaCl]} = 0.2500 \text{ M NaCl} \]
\[ \frac{V}{C} = 0.2500 \text{ M NaCl} \]

\[ 0.02500 \text{ M NaCl} \]

\[ 0.2500 \text{ M NaCl} \]

\[ V_{\text{loss}} = 0.3125 \text{ M NaCl} \]

\[ V_{\text{loss}} = 100.0 \text{ mL} - 80.00 \text{ mL} \]

\[ V_{\text{loss}} = 20.0 \text{ mL} \]
16. Potassium superoxide, KO₂, is used in life-support systems to replace the CO₂(g) in expired air with O₂(g). A balanced chemical equation for this process is shown below.

\[ 4 \text{ KO}_2(s) + 2 \text{ CO}_2(g) \rightarrow 2 \text{ K}_2\text{CO}_3(s) + 3 \text{ O}_2(g) \]

Molar Mass (g/mole)  71.0971  44.010  138.206  31.9988

a.) If you start with 45.0 g of KO₂ and 11.5 g of CO₂, what mass of O₂ will you generate? (10 points)

\[ \text{K}_2\text{O}_2 \quad \text{45.0 g K}_2\text{O}_2 \quad 1 \text{ mole K}_2\text{O}_2 \quad 31.9988 \text{ g O}_2 \quad = \quad 15.1189 \text{ g O}_2 \]

\[ \text{C}_2\text{O}_2 \quad \text{11.5 g C}_2\text{O}_2 \quad 1 \text{ mole C}_2\text{O}_2 \quad 31.9988 \text{ g O}_2 \quad = \quad 12.514 \text{ g O}_2 \]

b.) How much of each reactant will be left after the reaction is complete? (4 points)

\[ \text{C}_2\text{O}_2 = 0.96 \text{ g left} \]

\[ \text{K}_2\text{O}_2 \text{ that reacts} \]

\[ \text{12.514 g O}_2 \quad 1 \text{ mole O}_2 \quad 4 \text{ mole K}_2\text{O}_2 \quad 71.0971 \text{ g K}_2\text{O}_2 \quad = \quad 37.1558 \text{ g K}_2\text{O}_2 \]

\[ \text{Ant left} = 45.05 - 37.1558 = 7.8944 \quad = \quad 7.89 \text{ g K}_2\text{O}_2 \text{ left} \]

c.) If the above reaction produces only 10.00 g of O₂, what is the percent yield of the reaction? (2 points)

\[ \% \text{ yield} = \frac{a \times y \times 100}{t \cdot y} \]

\[ = \frac{10.00 \times 5 \times 100}{12.514} = 79.7 \% \]
17. In the table below, the name or formula for a chemical compound is given. Fill in the table with the corresponding name or formula of the chemical compound. (3 points)

<table>
<thead>
<tr>
<th>NAME</th>
<th>FORMULA</th>
</tr>
</thead>
<tbody>
<tr>
<td>iodic acid</td>
<td>HIO₃</td>
</tr>
<tr>
<td>cobalt(II) acetate</td>
<td>Co(C₂₃H₂₆O₂)₂</td>
</tr>
</tbody>
</table>

18. In the space provided below, draw a picture of a 3d orbital and a 4d orbital. Make sure to label which picture corresponds to the 3d orbital and which one corresponds to the 4d orbital and to point out the location of the nucleus. (3 points)

19. What is the condensed electron configuration of Sb³⁺? (3 points)

Sb: [Kr] 5s² 4d⁵ 5p³
Sb³⁺: [Kr] 5s² 4d⁰

20. What is the full electron configuration of argon (Ar)? (3 points)

Ar: 1s² 2s² 2p⁶ 3s² 3p⁶

21. What is the condensed orbital box diagram for Cu? How many valence electrons does Cu contain? (4 points)

Cu: [Ar] 4s¹ 3d¹

1 valence e⁻

22. a.) What is the full electron configuration of B? (2 points)

B: 1s² 2s² 2p¹

b.) In the space provided below, draw the Bohr Model representation of the boron atom and calculate the effective nuclear charge felt by the valence electrons. (4 points)
23. A 28.96 mL sample of $\text{H}_2\text{SO}_4$ is titrated with 0.4015 M KOH. The balanced chemical equation for the titration reaction is shown below.

$$2\text{KOH(aq)} + \text{H}_2\text{SO}_4(aq) \rightarrow \text{K}_2\text{SO}_4(aq) + 2\text{H}_2\text{O(l)}$$

a.) If the titration requires 42.56 mL of the KOH solution to reach the equivalence point, how many moles of $\text{H}_2\text{SO}_4$ were in the original solution? (6 points)

\[
\frac{42.56 \text{ mL} \times 0.4015 \text{ mol KOH}}{1 \text{ L} \times 2 \text{ mol KOH}} = 0.00854392 \text{ mol } \text{H}_2\text{SO}_4
\]

\[
= 0.008549 \text{ mol } \text{H}_2\text{SO}_4
\]

b.) What was the molarity of the original $\text{H}_2\text{SO}_4$ solution? (3 points)

\[
[\text{H}_2\text{SO}_4] = \frac{0.00854392 \text{ mol } \text{H}_2\text{SO}_4}{0.02896 \text{ L}} = 0.295029 \text{ M } \text{H}_2\text{SO}_4 = 0.2950 \text{ M } \text{H}_2\text{SO}_4
\]

c.) If 34.45 mL of deionized water was accidentally spilled into the flask before the titration, would the volume of KOH required to reach the equivalence point be larger, smaller, or equal to 42.56 mL. (1 point)

Equal to

24. The location of an element in the periodic table provides a wealth of information about effective nuclear charge, ionization energy, and electron affinity. Utilizing this information, it is possible to predict which elements are more likely to behave as oxidizing agents and which are more likely to behave as reducing agents. Use your knowledge of periodic trends to answer the following questions about the properties you would expect of an element that is a good reducing agent. Remember, a reducing agent loses electrons. Circle the best answer for each part. (4 points)

a.) $Z_{\text{eff}}$ felt by valence electrons → High or Low

b.) First Ionization Energy → High or Low

c.) Atomic Size → Large or Small

d.) Location of element on periodic table → Left hand side or Right hand side