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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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.

When NH₃ is combusted, it reacts with O₂ and produces N₂O and H₂O. The balanced chemical equation for this reaction is shown below. Use this equation and the diagrams below to answer the following two questions.

1. Which chemical was the limiting reactant?
   a.) NH₃
   b.) N₂O
   c.) H₂O
   
   d.) O₂
   e.) None of the above.

2. How many total molecules were in the container before the reaction started?
   a.) 8
   b.) 9
   c.) 10
   d.) 11
   e.) None of the above.

3. When a solution of K₂CrO₄(aq) is mixed with a solution of AgNO₃(aq), 1.33 g of Ag₂CrO₄ is produced. If the AgNO₃ solution has a concentration of 0.200 M, what volume of AgNO₃ solution reacted?

   \[ 2\text{AgNO}_3(\text{aq}) + \text{K}_2\text{CrO}_4(\text{aq}) \rightarrow \text{Ag}_2\text{CrO}_4(s) + 2\text{KNO}_3(\text{aq}) \]

   Molar Mass (g/mole)  
   169.8731  194.1903  331.7301  101.1032

   a.) 40.1 mL
   b.) 8.02 mL
   c.) 1.36 mL
   d.) 20.0 mL
   e.) None of the above.

\[ \frac{1.33 \text{g Ag}_2\text{CrO}_4}{331.7301 \text{g/mol}} \times \frac{1 \text{mol Ag}_2\text{CrO}_4}{2 \text{mol AgNO}_3} \times \frac{1 \text{L}}{0.200 \text{mol} \text{AgNO}_3} \times \frac{1000 \text{mL}}{1 \text{L}} = 40.019 \text{mL} = 40.1 \text{mL} \]
4. A chemist needs 225 mL of 2.4 M HCl. If the solution was made by diluting 12 M HCl, what volume of water was added to the concentrated HCl?

- (a) 80. mL
- (b) 21 mL
- (c) 45 mL
- (d) 225 mL
- (e) None of the above.

5. Which of the following has the smallest ionization energy?

- (a) Sb
- (b) I
- (c) Rb
- (d) Xe
- (e) Largest atom

6. The reaction shown below has a percent yield equal to 62.1%. If the actual yield of NO₂ is 49.0 g, what mass of O₂ must have reacted?

\[
\text{N}_2\text{H}_4(\text{g}) + 3\text{O}_2(\text{g}) \rightarrow 2\text{NO}_2(\text{g}) + 2\text{H}_2\text{O}(\text{g})
\]

- (a) 51.1 g
- (b) 50.4 g
- (c) 25.9 g
- (d) 82.3 g
- (e) None of the above.

7. Use the chemical equation below to calculate the moles of AlBr₃ that will be formed when 3.0 mole of Br₂ is reacted with an excess of Al.

\[2\text{Al(s)} + 3\text{Br}_2(\text{g}) \rightarrow 2\text{AlBr}_3(\text{s})\]

- (a) 2.0 mol
- (b) 3.0 mol
- (c) 4.0 mol
- (d) 6.0 mol
- (e) 8.0 mol
8. How many d electrons does a Ni atom contain?
   a.) 10  
   b.) 6  
   c.) 8  
   d.) 28  
   e.) None of the above.
   \[ \text{Ni: } 1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^8 \]

9. Of the group 1 metals shown below, which would serve as the best reducing agent? Remember, in oxidation-reduction reactions, a reducing agent loses electrons.
   a.) Cs  
   b.) Rb  
   c.) K  
   d.) Na  
   e.) Li
   \[ \text{largest atom} \]

10. A 20.00 mL solution of 0.3000 M HCl is titrated with a solution of Ca(OH)\(_2\). If the titration requires 48.00 mL of the Ca(OH)\(_2\) to reach the equivalence point, what was the molarity of the Ca(OH)\(_2\) solution?
    \[ \text{HCl(aq)} + \text{Ca(OH)\(_2\)}(aq) \rightarrow 2\text{H}_2\text{O(l)} + \text{CaCl}_2(\text{aq}) \]
    a.) 2.400\times10^{-4} \text{M}  
    b.) 0.1250 \text{M}  
    c.) 0.2500 \text{M}  
    d.) 0.06250 \text{M}  
    e.) None of the above
    \[ \frac{2 \text{HCl(aq)}}{1 \text{M} \text{Ca(OH)\(_2\)}} = \frac{\text{Ca(OH)\(_2\)}}{\text{M} \text{Ca(OH)\(_2\)}} = \frac{0.00300 \text{ mol \text{Ca(OH)\(_2\)}}}{0.0480 \text{ L}} = 0.06250 \text{ M Ca(OH)\(_2\)}} \]

11. A 2.500 M NaOH solution contains 0.3650 moles of NaOH. What is the volume (mL) of the solution?
    a.) 6849 mL  
    b.) 146.0 mL  
    c.) 912.5 mL  
    d.) 250.0 mL  
    e.) None of the above.
    \[ \frac{0.3650 \text{ mol NaOH}}{2.500 \text{ mol NaOH}} = 146.0 \text{ mL} \]

12. Which of the elements listed below has the electron configuration [Kr]5s\(^2\)4d\(^{10}\)5p\(^3\) ?
    a.) As  
    b.) Sb  
    c.) Nb  
    d.) Pr  
    e.) None of the above.
13. Certain reactions will give off or release energy when they occur. This energy can be used in a number of ways, including powering vehicles, heating homes, and cooking. The reaction shown below releases 241.8 kJ of energy. Since it releases energy, energy can be listed as a product in the balanced chemical equation and can be treated like any other product in stoichiometric calculations.

\[ 2\text{H}_2(g) + \text{O}_2(g) \rightarrow 2\text{H}_2\text{O}(g) + 241.8 \text{ kJ} \]

Molar Mass (g/mole)  
2.01588 31.9988 18.0153

How much energy will be released when 0.453 g of H\(_2\) reacts with excess O\(_2\)? (A kJ is just a unit of energy)

a.) 242 kJ  
b.) 27.2 kJ  
c.) 54.3 kJ  
d.) 110. kJ  
e.) None of the above.

\[ \frac{0.453 \text{ g H}_2}{2.01588 \text{ g H}_2} \times \frac{241.8 \text{ kJ}}{2 \text{ mol H}_2} = 27.16 \text{ kJ} \]

14. How many unpaired electrons does Mo contain? Use the orbital box diagram for Mo to help you answer the question.

a.) 2  
b.) 3  
c.) 4  
d.) 5  
e.) 6

15. A solution is prepared by dissolving 0.05146 moles of Na\(_2\)SO\(_4\) in enough water to make 225 mL of solution. What is the molarity of sodium ions?

a.) 0.0325 M  
b.) 0.000229 M  
c.) 0.229 M  
d.) 0.457 M  
e.) None of the above.

\[ \frac{0.05146 \text{ mol Na}_2\text{SO}_4}{2 \text{ mol Na}_2\text{SO}_4} \times \frac{1 \text{ mol Na}_2\text{SO}_4}{0.225 \text{ L}} = 0.457 \text{ M Na}_2\text{SO}_4 \]

\[ = 0.457 \text{ M Na}_+ \]

\[ = 0.457 \text{ M Na}_+ \]
16. 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. (6 points)

<table>
<thead>
<tr>
<th>NAME</th>
<th>FORMULA</th>
</tr>
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<tbody>
<tr>
<td>aluminum nitrite</td>
<td>Al(NO₂)₃</td>
</tr>
<tr>
<td>magnesium carbonate</td>
<td>Mg²⁺ CO₃²⁻ MgCO₃</td>
</tr>
<tr>
<td>periodiz acid</td>
<td>HIO₄</td>
</tr>
</tbody>
</table>

17. Pyrophosphoric acid, H₄P₂O₇, is sometimes used in the electroplating of copper. A sample of water containing pyrophosphoric acid found in a copper electroplating plant was titrated with 0.4563 M NaOH. The equation for the titration reaction is shown below.

\[
\text{H}_4\text{P}_2\text{O}_7(\text{aq}) + 4\text{NaOH}(\text{aq}) \rightarrow \text{Na}_4\text{P}_2\text{O}_7(\text{aq}) + 4\text{H}_2\text{O}(\text{l})
\]

Molar Mass (g/mol)  
177.9751  
39.9971   265.9024  18.0153

a.) If the titration required 31.02 mL of the 0.4563 M NaOH solution, what was the mass of pyrophosphoric acid in the sample of water? (7 points)

\[
\frac{31.02 \text{ mL}}{1000 \text{ mL}} \times 0.4563 \text{ mol NaOH} \times \frac{1 \text{ mol H}_4\text{P}_2\text{O}_7}{4 \text{ mol NaOH}} \times 177.9751 \text{ g H}_4\text{P}_2\text{O}_7 = 0.629718 \text{ g H}_4\text{P}_2\text{O}_7
\]

\[
= 0.6298 \text{ g H}_4\text{P}_2\text{O}_7
\]

b.) If the endpoint of the titration was not actually pink, is the mass of pyrophosphoric acid you calculated above too large, too small, or just right? Assume the indicator used was the same as the one you used in lab this semester. (3 points)

too small
18. What is the condensed orbital box diagram for Zn$^{2+}$? (3 points)

\[ \text{Zn} : \begin{array}{c} 4s^2 \ 3d^1 \\ 2s^2 \ 2p^6 \ 3s^2 \ 3p^3 \end{array} \]

19. In the space below, draw a picture of a 1s orbital and a 2s orbital. In your diagrams, point out the location of the nucleus. (2 points)

\[ \text{1s} \quad \text{2s} \]

20. In the space provided below give a.) the full electron configuration of the element that is underlined, b.) draw the Bohr representation of each element, and c.) calculate the effective nuclear charge ($Z_{\text{eff}}$) felt by the valence electrons in each of the atoms. (8 points)

a.) \[ \text{P} : 1s^2 \ 2s^2 \ 2p^6 \ 3s^2 \ 3p^3 \]

b.)

\[ Z_{\text{eff}} = 18 - 10 = 8 \]

a.) \[ \text{Cl} : 1s^2 \ 2s^2 \ 2p^6 \ 3s^2 \ 3p^5 \]

b.)

c.) \[ Z_{\text{eff}} = 17 - (10) = 7 \]

21. Suppose both of the elements above absorbed a photon of 750 nm light and had an electron promoted to an excited state.

a.) What color of light was absorbed? (1 point)

[Red]

b.) In which atom did the electron travel the shortest distance? (2 points)

[Cl]
22. Tetraphosphorus trisulfide, \( \text{P}_4\text{S}_3 \), is used in the heads of wooden matches. This material can be manufactured by heating a mixture of red phosphorus and sulfur. The balanced chemical equation for this process is shown below.

\[
8\text{P}_4(\text{s}) + 3\text{S}_8(\text{s}) \rightarrow 8\text{P}_4\text{S}_3(\text{s})
\]

Molar Mass (g/mole)

- \( \text{P}_4 \): 123.8950
- \( \text{S}_8 \): 256.528
- \( \text{P}_4\text{S}_3 \): 220.093

a.) If you start with 86.7 g of \( \text{P}_4 \) and 71.8 g of \( \text{S}_8 \), what mass of \( \text{P}_4\text{S}_3 \) will you produce? (13 points)

\[
\frac{86.7 \text{ g P}_4}{1 \text{ mol P}_4} \times \frac{1 \text{ mol P}_4\text{S}_3}{220.093 \text{ g P}_4\text{S}_3} = 154.10 \text{ g P}_4\text{S}_3
\]

\[
\frac{71.8 \text{ g S}_8}{1 \text{ mol S}_8} \times \frac{8 \text{ mol P}_4\text{S}_3}{220.093 \text{ g P}_4\text{S}_3} = 164.12 \text{ g P}_4\text{S}_3
\]

\[
\begin{array}{c}
\text{P}_4 \text{ is C.R.} \\
\text{0 g P}_4 \text{ left}
\end{array}
\]

b.) What mass of each reactant will be left after the reaction is complete? (7 points)

\[
\frac{154.10 \text{ g P}_4\text{S}_3}{1 \text{ mol P}_4\text{S}_3} \times \frac{3 \text{ mol S}_8}{8 \text{ mol P}_4\text{S}_3} = 71.31 \text{ g S}_8
\]

\[
\frac{220.093 \text{ g P}_4\text{S}_3}{1 \text{ mol P}_4\text{S}_3} \times \frac{8 \text{ mol P}_4\text{S}_3}{3 \text{ mol S}_8} = 71.31 \text{ g P}_4\text{S}_3
\]

\[
\text{S}_8 \text{ left} \\
71.31 \text{ g } - 67.31 \text{ g } = 4.0 \text{ g S}_8
\]

\[
= 4.5 \text{ g S}_8
\]