Final Exam - Chem 210 - Fall 2003

Multiple Choice
Identify the letter of the choice that best completes the statement or answers the question.

___ 1. All atoms of the same element have the same number of
   a. neutrons    d. neutrons and protons
   b. electrons   e. neutrons, protons, and electrons
   c. protons

___ 2. What is the result of the following expression expressed to the appropriate number of significant digits?
   \( 6.8 + 8.3 \)
   a. 0.0522   b. 0.052   c. 0.05   d. 0.05218   e. 0.52

___ 3. How many electrons are in \( ^{16}_{22} \text{Ti}^{+} \)?
   a. 18   b. 22   c. 26   d. 44   e. 52

___ 4. The density of lithium is 0.546 g/cm\(^3\). What volume is occupied by 3.66 \times 10^{23} \text{atoms of lithium}?
   a. 2.30 cm\(^3\)   b. 6.24 cm\(^3\)   c. 6.94 cm\(^3\)   d. 7.25 cm\(^3\)   e. 7.73 cm\(^3\)

___ 5. Identify the ions in \((\text{NH}_4)_2\text{SO}_4\)
   a. \text{N}^+; \text{H}^-; \text{S}^2-; \text{and O}^{2-}
   b. \text{NH}_4^+ \text{ and } \text{SO}_4^{2-}
   c. \text{NH}_4^+ \text{ and } \text{SO}_4^2-\text{ and } \text{O}^{2-}
   d. \text{NH}_2^+ \text{ and } \text{H}_2\text{SO}_4
   e. \text{NH}_4^+ \text{ and } \text{SO}_4^2-

___ 6. Which formula represents the binary compound formed by strontium ions and phosphate ions?
   a. \text{Sr}_2(\text{PO}_4)_3   b. \text{SrPO}_4   c. \text{Sr}_2\text{P}_3   d. \text{Sr}(\text{PO}_4)_2   e. \text{SrP}

___ 7. What is the correct name of \text{Sc}_2(\text{SO}_4)_3?
   a. discandium trisulfite   d. scandium(III) sulfur tetraoxide
   b. scandium(III) sulfate   e. scandium(III) trisulfate
   c. scandium(II) sulfate

___ 8. How many moles are there in 6.75 g of anhydrous copper(II) sulfate?
   a. 0.0928 mol   b. 1080 mol   c. 0.0423 mol   d. 0.321 mol   e. 0.00287 mol

___ 9. Aluminum reacts with oxygen to produce aluminum oxide: \( 4 \text{Al}(s) + 3 \text{O}_2(g) \rightarrow 2 \text{Al}_2\text{O}_3(s) \)
   If 3.0 moles of \text{Al} react with excess \text{O}_2, how many moles of \text{Al}_2\text{O}_3 can be formed?
   a. 1.5 mol   b. 2.0 mol   c. 2.7 mol   d. 3.0 mol   e. 4.5 mol

___ 10. Which of the following compounds are likely to be insoluble in water: \text{Na}_2\text{CO}_3, \text{AgNO}_3, \text{ZnS}, \text{KOH}, \text{Cu(OH)}_2, \text{and NH}_4\text{Cl}?
   a. \text{ZnS} and \text{NH}_4\text{Cl}   d. \text{Na}_2\text{CO}_3, \text{ZnS}, and \text{KOH}
   b. \text{KOH} and \text{Cu(OH)}_2   e. \text{ZnS} and \text{Cu(OH)}_2
   e. \text{AgNO}_3, \text{Cu(OH)}_2, and \text{NH}_4\text{Cl}

___ 11. What is the net ionic equation for the reaction of potassium hydroxide and hydrochloric acid?
   a. \text{H}^+(aq) + \text{KOH}(aq) \rightarrow \text{H}_2\text{O}(l) + \text{K}^+(aq)
   b. \text{K}^+(aq) + \text{Cl}(aq) \rightarrow \text{KCl}(aq)
   c. \text{HCl}(aq) + \text{KOH}(aq) \rightarrow \text{H}_2\text{O}(l)
   d. \text{H}^+(aq) + \text{OH}^-(aq) \rightarrow \text{H}_2\text{O}(l)
   e. \text{KOH}(aq) + \text{H}_2\text{O}(l) \rightarrow \text{H}^+(aq) + \text{K(OH)}_2(s)

___ 12. Which compound is the reducing agent in the reaction below?
   \( \text{I}^-(aq) + \text{ClO}^-(aq) \rightarrow \text{IO}^-(aq) + \text{Cl}^-(aq) \)
   a. \text{I}^-   b. \text{ClO}^-   c. \text{H}_2\text{O}   d. \text{IO}^-   e. \text{Cl}^-

___ 13. What is the oxidation number of phosphorus in \text{CaHPO}_4?  \text{a}. -3   \text{b}. -1   \text{c}. +1   \text{d}. +3   \text{e}. +5

___ 14. If 4.39 g \text{AlCl}_3 is dissolved in enough water to make exactly 100.0 mL of solution, what is the molar concentration of chloride ion? (molar mass of \text{AlCl}_3 = 133.3 g/mol)
   a. 0.0234 M   b. 0.0934 M   c. 0.110 M   d. 0.132 M   e. 0.988 M
15. What is the mass, in grams, of solute in 0.175 L of 3.17 \times 10^{-3} \text{ M KCl}?
   
   a. 0.00555 g  b. 0.181 g  c. 0.255 g  d. 0.414 g  e. 13.5 g

16. If 34.8 J is required to change the temperature of 10.0 g of mercury by 25 K, what is the specific heat of mercury?
   
   a. 0.139 J/g K  b. 0.338 J/g K  c. 0.718 J/g K  d. 0.870 J/g K  e. 1.93 J/g K

17. Which of the following colors of visible light has the shortest wavelength?
   
   a. orange  b. blue  c. green  d. red  e. yellow

18. A microwave oven emits radiation at a wavelength of 5.00 millimeters. What is the frequency of this radiation?
   
   a. 1.67 \times 10^9 \text{ s}^{-1}  
   b. 6.00 \times 10^9 \text{ s}^{-1} 
   c. 6.00 \times 10^{10} \text{ s}^{-1} 
   d. 1.50 \times 10^{10} \text{ s}^{-1} 
   e. 6.00 \times 10^{10} \text{ s}^{-1}

19. According to the Bohr model for the hydrogen atom, the energy necessary to excite an electron from \( n = 6 \) to \( n = 7 \) is ______ the energy necessary to excite an electron from \( n = 2 \) to \( n = 3 \).
   
   a. less than  b. greater than  c. either less than or equal to  d. equal to  e. greater than or equal to

20. What type of orbital is designated \( n = 4, \ell = 2, m_{\ell} = +1 \)?
   
   a. 4s  b. 4p  c. 4d  d. 2f  e. none

21. All of the following sets of quantum numbers are allowed EXCEPT
   
   a. \( n = 6, \ell = 3, m_{\ell} = -3 \)  
   b. \( n = 2, \ell = 1, m_{\ell} = 0 \)  
   c. \( n = 5, \ell = 0, m_{\ell} = -1 \)  
   d. \( n = 4, \ell = 2, m_{\ell} = +2 \)  
   e. \( n = 1, \ell = 0, m_{\ell} = 0 \)

22. Which of the following orbitals might have an \( m_{\ell} \) equal to +2?
   
   a. \( s \)  b. \( s \) and \( p \)  c. \( p \) and \( d \)  d. \( s \) and \( f \)  e. \( d \) and \( f \)

23. What is the maximum number of electrons that can exist in the shell \( n = 4 \)?
   
   a. 2  b. 8  c. 18  d. 32  e. 50

24. What is the electron configuration for Gold?
   
   a. \([\text{Xe}]6s^24p^6d^{10}\)  
   b. \([\text{Xe}]6s^24p^6d^{10}\)  
   c. \([\text{Xe}]6s^24p^6d^{10}\)

25. Which of the following elements would have the greatest difference between the first and the second ionization energies?
   
   a. Na  b. Sr  c. Cu  d. Cl  e. Sc

26. The change in energy for the following reaction is referred to as the ______ for oxygen: \( \text{O}(g) + e^- \rightarrow \text{O}(g) \)

   a. second ionization energy  
   b. first ionization energy  
   c. electron affinity  
   d. electronegativity energy  
   e. oxidation energy

27. What is the bond order for a nitrogen-oxygen bond in nitrate ion, \( \text{NO}_3^- \)?
   
   a. 1  b. 4/3  c. 3/2  d. 2  e. 3

28. Use VSEPR theory to predict the SHAPE of \( \text{SF}_2 \).

   a. bent  b. trigonal pyramidal  c. octahedral  
   d. linear  e. tetrahedral

29. How many neutrons are in an atom of the chromium-53 atom?
   
   a. 24  b. 53  c. 52  d. 29  e. 77

30. What are the bond angles in \( \text{SiH}_2 \)?

   a. 90°  b. 109.5°  c. 120°  d. 180°  e. 90° and 109.5°
31. How many sigma (σ) bonds and pi (π) bonds are in the following molecule?

\[ \text{H}_3\text{C}\text{H}_2\text{H}_2\text{H} \]

a. seven σ and two π 

b. six σ and two π 

c. eleven σ and zero π 

d. nine σ and two π 

e. two σ and nine π 

32. What is the arrangement of hybrid orbitals around an atom that is \( sp^3d \) hybridized?

a. tetrahedral  

b. trigonal bipyramidal  

c. octahedral  

d. square pyramidal  

e. see-saw 

33. Which of the following hybridized atoms is not possible?

a. an \( sp^2 \) hybridized oxygen atom  

b. an \( sp^2 \) hybridized nitrogen atom  

c. an \( sp^3 \) hybridized carbon atom  

d. an \( sp^2 \) hybridized oxygen atom  

34. Refer to Molecular Orbital Diagram. According to molecular orbital theory, which of the following lists places the nitrogen species in terms of increasing bond order?

a. \( N_2 < N_2 < N_2 < N_2 < N_2 \)  

b. \( N_2 < N_2 < N_2 < N_2 < N_2 \)  

c. \( N_2 < N_2 < N_2 < N_2 < N_2 \)  

35. Refer to Molecular Orbital Diagram. Which species has the shortest bond length?

a. \( N_2 \)  

b. \( N_2 \)  

c. \( N_2 \)  

d. \( N_2 \)  

e. \( N_2 \)  

36. At 0.966 atm, the height of mercury in a barometer is 734 mm. If the mercury was replaced with water, what height of water (in meters) would be supported at 0.966 atm? The densities of Hg and H₂O are 13.5 g/cm³ and 1.00 g/cm³, respectively.

a. 3.19 m  

b. 9.91 m  

c. 13.0 m  

d. 18.4 m  

e. 29.2 m  

37. If the pressure of a confined gas is tripled while its temperature remains constant, what change will be observed?

a. The volume of the gas will triple.  

b. The volume of the gas will decrease to 1/3 its original value.  

c. The density of the gas will decrease to 1/3 its original value.  

d. The volume will remain unchanged and the velocity of the molecules will increase.  

e. The volume will remain unchanged and the velocity of the molecules will decrease.  

38. A balloon is filled with \( \text{H}_2 \) gas to a volume of 2.60 \( \text{L} \) at 27°C. The balloon is then placed in liquid nitrogen until its temperature reaches -125°C. What is the volume of the cooled balloon?

a. 0.780 \( \text{L} \)  

b. 0.934 \( \text{L} \)  

c. 1.28 \( \text{L} \)  

d. 5.27 \( \text{L} \)  

e. 0.562 \( \text{L} \)  

39. If 3.25 g \( \text{N}_2 \) gas is introduced into an evacuated 1.50 \( \text{L} \) flask at 325 K, what is the pressure inside the flask? (\( R = 0.08206 \text{ L atm/mol K} \))

a. 0.330 atm  

b. 0.485 atm  

c. 1.29 atm  

d. 2.06 atm  

e. 57.8 atm  

40. Arrange \( \text{KCl}, \text{CH}_3\text{CH}_2\text{OH}, \text{C}_6\text{H}_6, \text{He} \) in order of increasing boiling point.

a. \( \text{C}_6\text{H}_6 < \text{He} < \text{KCl} < \text{CH}_3\text{CH}_2\text{OH} \)  

b. \( \text{C}_6\text{H}_6 < \text{He} < \text{CH}_3\text{CH}_2\text{OH} < \text{KCl} \)  

c. \( \text{He} < \text{KCl} < \text{C}_6\text{H}_6 < \text{CH}_3\text{CH}_2\text{OH} \)  

d. \( \text{He} < \text{C}_6\text{H}_6 < \text{CH}_3\text{CH}_2\text{OH} < \text{KCl} \)  

e. \( \text{KCl} < \text{He} < \text{C}_6\text{H}_6 < \text{CH}_3\text{CH}_2\text{OH} \)
Skyline Chemistry 210  
Final Exam  •  Fall 2003

Name: ______________________________

FREE RESPONSE: Answer the following questions in the spaces provided. Show all work and units to receive credit.

**Answer ALL of the questions on this page.**

1. (30 points) Write **complete, balanced equations** for the following chemical reactions (including state symbols). If you expect no reaction, write NR and explain why.
   
   A. Aqueous solutions of aluminum nitrate and magnesium hydroxide are mixed.
   
   B. Copper metal is placed into a solution of hydrochloric acid (HCl).
   
   C. Chlorine gas (Cl₂) is bubbled through a solution of nickel (III) bromide.

2. (10 points) Write the reaction that will have an enthalpy of reaction equal to the standard heat of formation of aluminum chloride (AlCl₃).

3. (15 points) Balance the following REDOX reaction in **acidic solution**.
   
   $\text{Zn}(\text{aq}) + \text{NO}_3^-(\text{aq}) \rightarrow \text{Zn}^{2+}(\text{aq}) + \text{N}_2\text{O}_5(\text{g})$ in acidic aqueous solution.

4. (27 points) Draw the electron dot structure, name the shape, and indicate whether the molecule is POLAR or NON-POLAR. Assume a single central atom.

<table>
<thead>
<tr>
<th>AsBr₄</th>
<th>SO₃</th>
<th>PI₃</th>
</tr>
</thead>
<tbody>
<tr>
<td>SHAPE:</td>
<td>SHAPE:</td>
<td>SHAPE:</td>
</tr>
<tr>
<td>Molecular Polarity?</td>
<td>Molecular Polarity?</td>
<td>Molecular Polarity?</td>
</tr>
</tbody>
</table>

5. (15 points) Consider the polyatomic ion below. **Indicate the formal charge of ALL atoms on the structure.**

   ![Polyatomic Ion]

   What is the OVERALL charge of the polyatomic ion? _____________

   Draw two additional resonance structures of this polyatomic ion.

   ![Resonance Structures]
Answer the following question (#6). (28 points)

6. A 10.0-g sample of disulfur dioxide is treated with 10.0-g of fluorine gas to produce SF₆ and oxygen as a byproduct:

\[
\text{S}_2\text{O}_2(\text{g}) + 6 \ \text{F}_2(\text{g}) \rightarrow 2 \ \text{SF}_6(\text{g}) + \ \text{O}_2(\text{g})
\]

<table>
<thead>
<tr>
<th>Molar Masses</th>
<th>Compound</th>
<th>( M_m ) (g/mol)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \text{S}_2\text{O}_2 )</td>
<td>96.14</td>
<td></td>
</tr>
<tr>
<td>( \text{F}_2 )</td>
<td>38.00</td>
<td></td>
</tr>
<tr>
<td>( \text{SF}_6 )</td>
<td>146.07</td>
<td></td>
</tr>
<tr>
<td>( \text{O}_2 )</td>
<td>32.00</td>
<td></td>
</tr>
</tbody>
</table>

A. What mass of \( \text{SF}_6 \) can be produced?

B. What mass of excess reagent remains at the end of the reaction?

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Answer 1 of the following 2 questions on this page (#7 or #8). (25 points)

7. A 250.0 mL sample of a 3.50 \( M \) solution of hydrogen peroxide is treated with a catalyst to speed its decomposition into water and oxygen gas:

\[
2 \ \text{H}_2\text{O}_2(aq) \xrightarrow{\text{MnO}_2} 2 \ \text{H}_2\text{O}(l) + \ \text{O}_2(g)
\]

What volume will the dry (no water vapor) oxygen gas produced by this reaction occupy at 23.0°C and 745 mmHg?

8. A 0.564-g sample of a compound that contains only phosphorus and oxygen was subjected to analysis and found to contain 0.246-g of phosphorus. In a separate experiment, the compound was found to have a molar mass of 284 g/mol. What are the empirical and molecular formulas of the compound?
9. Consider the reaction of nitric acid with carbon monoxide to produce nitrous acid and CO₂:

\[ \text{HNO}_3(\text{aq}) + \text{CO}_2(\text{g}) \rightarrow \text{HNO}_2(\text{aq}) + \text{CO}_2(\text{g}) \]

What quantity of heat will be produced or consumed when 3.00 g of carbon monoxide is bubbled through a solution containing excess nitric acid and completely reacts?

(You can find a table of bond energy approximations on the reference handout. Do not consider resonance. Obey the octet rule in all structures.)

10. A 1.35-g sample of elemental sulfur is burned in a calorimeter with a heat capacity of 278 J/C° that contains 425 g of water. If the temperature of the water and calorimeter rises from 22.36 °C to 26.59°C, what is the ΔH (in kJ) for the reaction below as written?

\[ 2 \text{S}_2(\text{s}) + 3 \text{O}_2(\text{g}) \rightarrow 2 \text{SO}_3(\text{g}) \]

11. Using heats of formation, calculate the heat of reaction for the combustion of benzene, C₆H₆(ℓ), in kJ/mol and in J/g.

12. A) Calculate the heat of the overall reaction given the enthalpies of the reactions below:

- \[ 2 \text{Mg}(s) + \text{O}_2(\text{g}) \rightarrow 2 \text{MgO}(s) \]
  \[ \Delta H = -322 \text{ kJ} \]

- \[ \text{C}(s) + \text{O}_2(\text{g}) \rightarrow \text{CO}_2(\text{g}) \]
  \[ \Delta H = -393 \text{ kJ/mol} \]

- \[ 2 \text{Mg}(s) + 2 \text{C}(s) + 3 \text{O}_2(\text{g}) \rightarrow 2 \text{MgCO}_3(\text{s}) \]
  \[ \Delta H = -626 \text{ kJ} \]

B) Draw an energy diagram that illustrates the relationships of the ΔH values for each of the above reaction steps and the overall reaction. Clearly label the energy change for each step.