CHEM 210 - Exam 3 - Fall 2009

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

_____ 1. Use VSEPR theory to predict the SHAPE of ScI₂
   A) bent C) perpendicular E) linear
   B) trigonal planar D) tetrahedral

_____ 2. Consider the following diagram. Following class conventions, what is the full set of four quantum numbers for circled electron?

   \[ \text{6d} \]
   \[ \uparrow \downarrow \uparrow \downarrow \]

   A) \( n = 5 \) \( l = 3 \) \( m_l = +2 \) \( m_s = -1/2 \)
   B) \( n = 6 \) \( l = 2 \) \( m_l = -2 \) \( m_s = +1/2 \)
   C) \( n = 6 \) \( l = 3 \) \( m_l = 0 \) \( m_s = +1/2 \)
   D) \( n = 6 \) \( l = 2 \) \( m_l = +1 \) \( m_s = +1/2 \)
   E) none of these.

_____ 3. Which of the following transitions requires the \textit{absorption} of a photon with the \textit{highest} energy? (No calculation is required.)

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

_____ 4. What atoms in the 3rd row of the periodic table would most likely have the following ionization energies (in kJ/mol)?

\[
\begin{align*}
1\text{st} & = 1,220 \\
2\text{nd} & = 2,150 \\
3\text{rd} & = 3,890 \\
4\text{th} & = 6,330 \\
5\text{th} & = 42,030 \\
6\text{th} & = 51,600 \\
7\text{th} & = 72,300 \\
8\text{th} & = 81,500
\end{align*}
\]

   A) Al  B) Si  C) Mg  D) Cl  E) Ar

_____ 5. How many orbitals could have the designation 5g?
   A) 9  B) 8  C) 5  D) 11  E) 1
6. How many *orbitals* can have the designation: n = 2  l = 2
   A) 5   B) 6   C) 3   D) 7   E) none

7. An atom has the following ionization energies (all in kJ/mol):
   1st:  800
   2nd:  2426
   3rd:  3659
   4th:  25020
   5th:  32820
   What is the most likely charge for an ion of this element?
   A) +1   B) +5   C) +2   D) +4   E) +3

8. Put the following in order of increasing first ionization energy: Ca  Cl  Mg  Na
   A) Na < Mg < Cl < Ca   C) Na < Ca < Mg < Cl
   B) Cl < Ca < Mg < Na   D) Mg < Ca < Na < Cl

9. Which of the following is the longest bond?

10. How many *orbitals* can have the designation: n = 4  l = 1  m_l = -1
    A) 3   B) 6   C) 1   D) 2   E) none

11. Which of the following represents the reaction for the third ionization energy for Aluminum?
    A) Al → Al^{3+} + 3 e^-   D) Al + 3 e^- → Al^{3+}
    B) Al^{2+} → Al^{3+} + e^-   E) Al → Al^{3+} + e^-
    C) Al + 3 e^- → Al^{3+}

12. Put the following atoms in order of increasing particle size: Ca^{2+}  Cl^-  Se^{2-}
    A) Ca^{2+} < Cl^- < Se^{2-}   C) Cl^- < Se^{2-} < Ca^{2+}
    B) Ca^{2+} < Se^{2-} < Cl^-   D) Se^{2-} < Ca^{2+} < Cl^-
FREE RESPONSE: Answer the following questions in the spaces provided. Show all work and express final answers with the correct number of significant figures and units to receive full credit. If you use exponential notation for your answer, you must use proper scientific notation.

Note: If a solution requires determination of a limiting reagent, you must in some way indicate you have determined what the limiting reagent is.

1. (4 points) Write a reaction for which the $\Delta H_{\text{rxn}} = \Delta H_{\text{formation}}^\circ$ for NH$_4$Cl(s). Include states for all species.

2. (8 points) Consider the reaction: $2 \text{CO}_2(\text{g}) \rightarrow 2 \text{CO}(\text{g}) + \text{O}_2(\text{g})$

   A) Calculate $\Delta H$ for the reaction above given the equations below with the enthalpies indicated:

   $2 \text{CO}(\text{g}) \rightarrow 2 \text{C}(\text{s}) + \text{O}_2(\text{g}) \quad \Delta H = 218 \text{ kJ}$

   $\text{CO}_2(\text{g}) \rightarrow \text{C}(\text{s}) + \text{O}_2(\text{g}) \quad \Delta H = 393 \text{ kJ}$

   B) Draw an energy diagram that illustrates the relationships of the $\Delta H$ values for each of above reaction steps and the overall reaction.
3. (12 points) A 3.00 g sample of ethanol (C\textsubscript{2}H\textsubscript{5}OH\textsubscript{(l)}, M\textsubscript{m}= 45.06 g/mol) is burned with excess oxygen inside a bomb calorimeter (with a heat capacity you wish to determine) that holds 1.75 kg of water. The whole apparatus increases in temperature from 22.30 °C to 27.65 °C. **Determine the heat capacity (H\textsubscript{c}) of the calorimeter.**

The combustion of ethanol is described by the equation:

\[ \text{C}_2\text{H}_5\text{OH}(l) + 3 \text{O}_2(g) \rightarrow 2 \text{CO}_2(g) + 3 \text{H}_2\text{O}(g) \]

4. (8 points) Consider the reaction:

\[ 2 \text{N}_2\text{O}(g) + 4 \text{H}_2\text{O}(g) \rightarrow 2 \text{N}_2\text{H}_4(l) + 3 \text{O}_2(g) \]

If 6.25 g of dinitrogen monoxide is mixed with 8.00 g of water vapor, what quantity of heat is produced or consumed by the resulting reaction?
5. (8 points) To investigate the amount of heat absorbed by ammonium nitrate, 6.00 g NH$_4$NO$_3$ ($M_m = 80.05$ g/mol) is dissolved in 100.0 g of water at 24.5°C in a container that absorbs a negligible amount of heat. The final temperature of the solution is 21.2°C. The solution that results has a density of 1.02 g/mL a specific heat capacity of 4.21 J/g°C.

Based on these data, determine the enthalpy of solution (enthalpy of dissolving) for ammonium nitrate (ΔH) in kJ/mol.

\[ \text{NH}_4\text{NO}_3(s) \rightarrow \text{NH}_4\text{NO}_3(aq) \]

6. (7 points) The energy required to remove the outermost electron from a mole of beryllium atoms is 899 kJ/mol. What is the wavelength of a photon of EM radiation would have just enough energy to remove one electron from a single beryllium atom?

7. (4 points) Sketch the shape of a single p-orbital:  

Sketch the shape of a single d-orbital:

8. (9 points) Give the electron configuration for the following species. You may use noble gas abbreviations as appropriate.

K  

Ag  

Bi$^{5+}$

9. (6 points) Draw the electron dot structure for the sulfate ion: $\text{SO}_4^{2-}$

You may draw one reasonable resonance structure.

What is the SHAPE of the sulfate ion? ________________________________

What is the O-S-O bond angle? ________________

10. (6 points) Draw all of the reasonable resonance structures for the nitrite ion: $\text{NO}_2^-$

What is the N-O bond order in the ion? __________

What is the O-N-O bond angle? ________________

11. (6 points) Draw a reasonable Lewis structure for nitric acid: $\text{HNO}_3$

What is the hybridization on the N? ____________

Assign formal charges to all of the atoms in the structure.
12. (6 points) Consider the molecule: $\text{CH}_2\text{F}_2$ for which carbon is the single, central atom.

What is the SHAPE of the molecule?_________________________________________

Sketch the molecule.
   a. Indicate partial positive and negative charges on atoms, if there are any.
   b. If the overall molecule is polar, clearly show how you can determine its polarity in your sketch.
   c. If not, briefly explain.

13. (18 points) Provide the information requested for the following covalent molecules.

A) $\text{IF}_3$
   SHAPE = _________________________________
   BOND ANGLE = __________________
   Is the molecule  POLAR  or  NON-POLAR ?
   (please circle which it is.)

B) $\text{NCl}_3$
   SHAPE = _________________________________
   BOND ANGLE = __________________
   Is the molecule  POLAR  or  NON-POLAR ?
   (please circle which it is.)

C) $\text{AlBr}_3$
   SHAPE = _________________________________
   BOND ANGLE = __________________
   Is the molecule  POLAR  or  NON-POLAR ?
   (please circle which it is.)
CHEM 210 • Exam Reference Information

Notes on the Exam:
• All quantum numbers should follow the conventions discussed in the course for the assignment of orbital number & spin.
• ELECTRON ARRANGEMENT refers to the shape that the hybrid orbitals, regardless of being bonds or lone pairs.
• SHAPE refers to the shape of just the atoms in the molecule.
• All BOND ANGLES should be given to be as precise as possible.

General Equations and Information

\[ D = \frac{m}{V} \]

\[ D_{H_2O} = 1.00 \text{ g/mL} \]

kilo = \( k = 10^3 \)

nano = \( n = 10^{-9} \)

milli = \( m = 10^{-3} \)

**Absolute Zero** = \(-273.15 \, ^\circ\text{C}\)

**Avogadro’s Number** = \( N_A = 6.022 \times 10^{23} \)

Heat Constants & Equations

\[ q_{\text{system}} = q_{\text{surroundings}} \]

\[ q = mC_p\Delta T \]

\[ C_{p,H_2O} = 4.184 \text{ J/g} \cdot \text{°C} \]

\[ q_{\text{lost}} = q_{\text{gained}} \]

\[ q = (\text{heat capacity}) \Delta T \]

\( (\text{Heat capacity may be abbreviated as } H_c) \)

\[ \Delta H_{\text{reaction}} = \frac{q_{\text{reaction}}}{\text{moles reacting}} \]

\[ \Delta H_{\text{reaction}} = \frac{q_{\text{reaction}}}{\text{moles reacting}} \times \text{coefficient} \]

\[ \Delta H_{\text{rxn}} = \Sigma(n_p\Delta H_{f,\text{products}}) - \Sigma(n_r\Delta H_{f,\text{reactants}}) \]

**EM radiation and Hydrogen atom energy levels**

\[ c = \lambda \nu \]

\[ E = \frac{hc}{\lambda} \]

\[ E_{\text{photon}} = |\Delta E| \]

\[ E_a = -\frac{Rhc}{n^2} \]

\[ \Delta E = -Rhc\left(\frac{1}{n_{\text{final}}^2} - \frac{1}{n_{\text{initial}}^2}\right) \]

\[ N_A = 6.022 \times 10^{23} \]

\[ c = 3.00 \times 10^8 \text{ m/s} \]

\[ h = 6.626 \times 10^{-34} \text{ J} \cdot \text{s} \]

\[ \text{Rhc} = 2.18 \times 10^{-18} \text{ J} \]
Selected SHAPE Sketches

Electronegativities:

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Periodic Table: