CHE 141 Second Exam

October 28, 2011

This exam contains 8 questions, some with multiple parts. Write your answers to each question in the space provided. The points for each question are indicated at the end of each question. Overall this is a 100 point exam.

Avogadro’s number $N = 6.022 \times 10^{23}$ mol$^{-1}$
Mass of electron $m_e = 9.109 \times 10^{-31}$ kg
Planck’s constant $h = 6.626 \times 10^{-34}$ J s
Speed of light $c = 3.00 \times 10^8$ m s$^{-1}$
Gas constant $R = 0.08206$ L atm K$^{-1}$ mol$^{-1}$
Gas constant $R = 8.314$ J K$^{-1}$ mol$^{-1}$
0 K $= -273.15$ °C

Name____________________________________

Signature __________________________________________________

Section (Check One)

_________ Section 1     Monday Afternoon

_________ Section 2     Tuesday Morning

_________ Section 3     Tuesday Afternoon

Total Points ______________________
1. A student filled an empty 250.0 mL flask of known mass with an unknown hydrocarbon gas at a temperature of 24.0 °C and a pressure of 741 mm Hg. The mass of the filled flask was determined and by difference the mass of the gas was found to be 0.561 grams. What is the molecular weight of the gas? (12 points)

2. Gaseous effusion can be used to separate isotopes. Suppose you had a balloon filled with equal molar amounts of hydrogen, H₂, and deuterium, D₂, gas. After 10 hours you find that 20.0 % of the hydrogen, H₂, had effused out of the balloon along with some unknown amount of the deuterium, D₂.

What would be the molar percentage of D₂ gas in the balloon after this 10 hour period?

(Atomic Masses: H 1.01 grams/mol; D 2.01 grams/mol) (12 points)
3. The particle in the box model can be used to model the π electron systems of conjugated hydrocarbons.

\[ \text{\Large \text{\begin{tikzpicture}
        \draw (0,0) -- (1,0);
        \draw (1,0) -- (2,0);
        \draw (2,0) -- (3,0);
        \filldraw[black] (2,0) circle (2pt);
      
      \draw (2,-0.5) -- (2,0.5); \node at (2,-0.5) {560 pm};
      \end{tikzpicture}\text{\Large\big)}}\]

To model the compound butadiene, C₄H₆, you could consider its π system as four π electrons confined in a 560 pm box. ( 1 pm = 10⁻¹² m )

The energy levels in the particle in the box model are given by the equation:

\[ E_n = \frac{n^2 \hbar^2}{8mL^2} \]

Use this equation to calculate the wavelength of the lowest energy band in the electronic spectrum of butadiene. This would correspond to the transition from the highest occupied molecular orbital to the lowest unoccupied molecular orbital.

You may also need this equation: \[ E_{\text{photon}} = h\nu = \frac{hc}{\lambda} \] (12 points)
4. Use the coordinate axes shown below to sketch the shapes of the indicated atomic orbitals. (9 points)

a) 2 \( p_y \)

\[ \begin{array}{c}
\text{Z} \\
\text{Y} \\
\text{X}
\end{array} \]

b) 3 \( d_{xy} \)

\[ \begin{array}{c}
\text{Z} \\
\text{Y} \\
\text{X}
\end{array} \]

c) 3 \( d_{z^2} \)

\[ \begin{array}{c}
\text{Z} \\
\text{Y} \\
\text{X}
\end{array} \]
5. Name the orbital that would have the following quantum numbers. Or state **none** if there is no such orbital. (8 pts)

Example: \( n = 2 \quad l = 1 \quad m_l = 0 \) ______ orbital

1. \( n = 4 \quad l = 2 \quad m_l = +1 \) ______ orbital

2. \( n = 3 \quad l = 1 \quad m_l = -2 \) ______ orbital

3. \( n = 4 \quad l = 3 \quad m_l = +2 \) ______ orbital

4. \( n = 5 \quad l = 0 \quad m_l = 0 \) ______ orbital

6. Calculate \( \Delta H \) of formation for NaF(s). (12 pts)

\[
\text{Na(s)} + \frac{1}{2} \text{F}_2(g) \rightarrow \text{NaF(s)} \quad \Delta H_f = ?
\]

Using this data:

\[
\begin{align*}
\text{Na(s)} & \rightarrow \text{Na(g)} \quad \Delta H = 98 \text{ kJ/mol} \\
\text{Na(g)} & \rightarrow \text{Na}^+(g) + e^- \quad \Delta H = 495 \text{ kJ/mol} \\
\text{F}_2(g) & \rightarrow 2 \text{F}(g) \quad \Delta H = 154 \text{ kJ/mol} \\
\text{F}(g) + e^- & \rightarrow \text{F}^-(g) \quad \Delta H = -328 \text{ kJ/mol} \\
\text{Na}^+(g) + \text{F}^-(g) & \rightarrow \text{NaF(s)} \quad \Delta H = -930 \text{ kJ/mol}
\end{align*}
\]
7. For each of the following structures give a Lewis representation (including all important resonance structures), draw a three dimensional picture of the structure and name the structure.

NH₃ is given as an example.  

<table>
<thead>
<tr>
<th>Compound</th>
<th>Lewis Structure</th>
<th>Three Dimensional</th>
<th>Structure Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>NH₃</td>
<td>H(\cdot)N(\cdot)H</td>
<td>H(\cdot)N(\cdot)H</td>
<td>pyramidal</td>
</tr>
<tr>
<td>ClO(_3)⁻</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>XeF(_4)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BrF(_3)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(CH(_3))(_2)SO</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
8. The compound below is acetaldehyde. It has two kinds of hydrogen atoms, the methyl hydrogen atoms, A, and the aldehyde hydrogen, B. When acetaldehyde reacts with a strong base, one of these hydrogen atoms is easily removed as a proton.

![Acetaldehyde structure](image)

a. Draw a Lewis representation including all important resonance structures of the anion that results from removing proton A. (5 points)

b. Draw a Lewis representation including all important resonance structures of the anion that results from removing proton B. (5 points)

c. Which hydrogen is more acidic, A or B? Explain your answer. (5 points)

A or B (circle one)

Explain: