City College, Chemistry Department
Chemistry 10301, sections T, T2, T3. Prof. T. Lazaridis
Final exam, Dec 20, 2007
Name (last name first): _____________________________________________
I.D. Number last 4:_________________________________________________

Note: There are 18 questions in this exam. Fill in your answer in the blank space provided immediately following each question. 1/2 point will be subtracted every time you report a numerical result with an incorrect number of significant figures.

A Data Sheet with useful information is at the end.

1. (4) Write the names of the elements below next to their atomic symbols:

Ar     Argon
Al     Aluminum
S      Sulfur
Cu     Copper

2. (4) Write the molecular formula next to the names of the following compounds:

Sodium Nitrate     NaNO₃
Barium Carbonate   BaCO₃
Magnesium Sulfate  MgSO₄
Potassium Hydroxide KOH

3. (8) Balance the following chemical equations:

\[ \text{H}_2 + \text{I}_2 \rightarrow 2 \text{HI} \]

\[ 2 \text{As} + 3 \text{H}_2 \rightarrow 2 \text{AsH}_3 \]

\[ 2 \text{KClO}_3 \rightarrow 2 \text{KCl} + 3 \text{O}_2 \]

\[ 2 \text{K} + 2 \text{H}_2\text{O} \rightarrow 2 \text{KOH} + \text{H}_2 \]
4. (7) The equation for preparing chlorine gas from HCl is

\[ 4 \text{HCl (g)} + \text{O}_2 \text{(g)} \rightarrow 2 \text{Cl}_2 \text{(g)} + 2 \text{H}_2\text{O (g)} \]

How many kilograms of HCl are required to produce 1750 kilograms of Cl\(_2\)?

Molar masses: Cl\(_2\): 70.90 g/mol  \hspace{1cm} \text{HCl: 36.46 g/mol}

\[
1750 \text{ Kg} \times 1000\text{g/Kg} \times \left( \frac{1}{70.90 \text{ g/mol}} \right) \times \left( \frac{4 \text{ mol HCl}}{2 \text{ mol Cl}_2} \right) \times 36.46 \text{ g/mol} \times \left( \frac{1 \text{ Kg/1000 g}}{1} \right) = 1800 \text{ Kg HCl}
\]

5. (7) Chlorobenzene is prepared from benzene by the following reaction:

\[ \text{C}_6\text{H}_6 \text{(l)} + \text{Cl}_2 \text{(g)} \rightarrow \text{C}_6\text{H}_5\text{Cl (l)} + \text{HCl (g)} \]

A 10.0-Kg sample of benzene treated with excess chlorine gas yields 10.4 Kg of chlorobenzene. Calculate the percent yield of chlorobenzene.

Molar masses: C\(_6\)H\(_6\): 78.11 g/mol \hspace{1cm} \text{C}_6\text{H}_5\text{Cl: 112.55 g/mol}

\[
10000 \text{ g} / 78.11 \text{ (g/mol)} = 128.0 \text{ mol benzene}
\]

Theoretical yield = 128.0 mol \times 112.55 \text{ (g/mol)} = 14406 \text{ g chlorobenzene}

Percent yield: \( \frac{10.4}{14.4} \times 100\% = 72.2 \% \)

6. (7) How many L of oxygen, measured at 0 °C and 1.00 atm, are required for the complete combustion of 5.00 g of ethane (C\(_2\)H\(_6\))?  

\[ \text{C}_2\text{H}_6 + \frac{7}{2} \text{O}_2 \rightarrow 2 \text{CO}_2 + 3 \text{H}_2\text{O} \]

Molar mass: C\(_2\)H\(_6\): 30.07 g/mol

\[
5.00 / 30.07 \text{ (g/mol)} = 0.166 \text{ mol}, \hspace{1cm} \text{this requires} \ 0.166 \times \frac{7}{2} = 0.581 \text{ mol O}_2
\]

\[ \text{IG equation: } V = \frac{nRT}{P} = 0.581 \times 0.082 \times 273.15 \text{ K} / 1 \text{ atm} = 13.0 \text{ L} \]
7. (7) Oxidation of ammonia gives nitric oxide and water:

\[ 4 \text{NH}_3 (g) + 5 \text{O}_2 (g) \rightarrow 4 \text{NO} (g) + 6 \text{H}_2\text{O} (g) \quad \Delta H^\circ = -905.4 \text{ kJ} \]

Use this equation and data from your data sheet to calculate the enthalpy of formation of NO.

\[
\Delta H^\circ = \Delta H^\circ_r (\text{products}) - \Delta H^\circ_r (\text{reactants}) \Rightarrow \\
-905.4 = \{6 \times (\text{-241.8}) + 4 \Delta H^\circ_r (\text{NO})\} - \{4 \times (\text{-46.11})\} \Rightarrow \\
\Delta H^\circ_r (\text{NO}) = +90.2 \text{ kJ}
\]

8. (7) 30.0 g of \text{P}_4\text{O}_{10} is mixed with 75.0 g of water to form phosphoric acid:

\[ \text{P}_4\text{O}_{10} \text{ (s)} + 6 \text{H}_2\text{O} \text{ (l)} \rightarrow 4 \text{H}_3\text{PO}_4 \text{ (aq)} \]

a) (3) Which one is the limiting reactant?
b) (3) How many grams of phosphoric acid will form?

a) Molar masses: \text{P}_4\text{O}_{10}: 283.88 \text{ g/mol} \quad \text{H}_2\text{O}: 18.02 \text{ g/mol} \quad \text{H}_3\text{PO}_4 : 97.99 \text{ g/mol}

\[
\frac{30.0}{283.88} = 0.106 \text{ mol} \text{P}_4\text{O}_{10} \quad \frac{75.0}{18.02} = 4.16 \text{ mol} \text{H}_2\text{O}
\]

0.106 mol \text{P}_4\text{O}_{10} requires 6 \times 0.106 mol = 0.636 mol water. We have 4.16. So water is in excess and limiting reactant is \text{P}_4\text{O}_{10}.

b) 0.106 \times 4 \times 97.99 \text{ g/mol} = 41.55 \text{ g} \text{H}_3\text{PO}_4
9. (4) Calculate the molarity of each of the following solutions:

a) (2) 45.0 g of NaCl in 250 mL of solution

\[
\text{Molar mass : 58.44} \quad \frac{45.0}{58.44} = 0.770 \text{ mol}
\]
\[
0.707 \text{ mol} / 0.25 \text{ L} = 3.08 \text{ M}
\]

b) (2) 40.0 g of H\textsubscript{2}SO\textsubscript{4} in 2.00 L of solution

\[
\text{Molar mass : 98.09} \quad \frac{40.0}{98.09} = 0.408 \text{ mol}
\]
\[
0.408 \text{ mol} / 2 \text{ L} = 0.204 \text{ M}
\]

10. (4) How many orbitals are there in

a) (2) the n=3 shell?

9 (1 3s, 3 3p, and 5 3d)

b) (2) the 3d subshell?

5

11. (4) Write an abbreviated (noble gas core) electron configuration for the following:

\[
\text{Si} \quad [\text{Ne}]3s^23p^2
\]
\[
\text{Cl}^- \quad [\text{Ar}]
\]
\[
\text{Cd} \quad [\text{Kr}]5s^24d^{10}
\]
\[
\text{Fe}^{3+} \quad [\text{Ar}]3d^5
\]

12. (2) Place the atoms B, K, Ga in order of increasing ionization energy.

\[
\text{K} < \text{Ga} < \text{B}
\]
13. (5) Draw the orbital diagram for the partially filled subshells of Cr.

(Cr is an exception to Aufbau rules)

14. (10) Draw Lewis structures that satisfy the octet rule for CO, CO$_2$, and CO$_3^{2-}$ and predict the order of the C–O bond lengths (which molecule will have the shortest, the longest, and the intermediate bond lengths).

\[
\begin{align*}
\text{C} & \equiv \text{O} \\
\text{O} & \equiv \text{C} \equiv \text{O} \\
\left[\begin{array}{c}
\text{O} \\
\text{O} \\
\text{O}
\end{array}\right] & \equiv \text{C} \equiv \text{O} \\
\left[\begin{array}{c}
\text{O} \\
\text{O} \\
\text{C}
\end{array}\right] & \equiv \text{O} \\
\end{align*}
\]

The C...O bond is shortest in CO (triple), intermediate in CO$_2$(double), and longest in CO$_3^{2-}$ (single with partial double bond character)

15. (5) Use Lewis structures and the VSEPR method to predict the molecular geometry and the bond angles of ClO$_3^-$

Electron group geometry: tetrahedral (bond angles slightly smaller than 109.5), molecular geometry: trigonal pyramidal

16. (5) Compare the shapes and bond angles of H$_2$O and H$_3$O$^+$. 
E.G. geometry tetrahedral, mol. geometry bent (angular), bond angle somewhat smaller than 109.5 due to lone pair repulsion

E.G. geometry tetrahedral, mol. geometry trigonal pyramidal, bond angle somewhat smaller than 109.5 due to lone pair repulsion (but probably not as small as in water)

17. (5) Write the structural formula for propene (C₃H₆), determine the hybridization of each central atom, and estimate all bond angles.

```
\begin{align*}
\text{H} & \quad \text{sp}^2 \\
\text{C} & \quad \text{sp}^2 \\
\text{H} & \quad \text{sp}^3 \\
\end{align*}
```

The angles around the left and center C are 120° and around the C on the right 109.5°

18. (5) Give the oxidation number of each element in the following compounds:

a) XeOF₂  \quad F : -1, O: -2, Xe: +4

b) Sn(OH)₄²⁻  \quad O: -2, H : +1, Sn: +2

c) PH₄⁺  \quad H : +1, P: -3

d) CuCl₄²⁻  \quad Cl : -1, Cu: +2

e) CN⁻  \quad N : -3, C: +2
DATA SHEET

Speed of light : $2.9979 \times 10^8 \text{ m/s}$

Planck's constant : $6.626 \times 10^{-34} \text{ Js}$

$E_n = -2.179 \times 10^{-18} \text{ J/n}^2$

Mass of a proton: $1.67262 \times 10^{-24} \text{ g}$

Mass of an electron: $9.10939 \times 10^{-28} \text{ g}$

$R = 0.082058 \text{ L atm / (mol K)} = 62.364 \text{ L torr / (mol K)} = 8.3145 \text{ J / (mol K)}$

<table>
<thead>
<tr>
<th>Substance</th>
<th>$\Delta H_f^\circ$, kJ/mol</th>
</tr>
</thead>
<tbody>
<tr>
<td>NH$_3$ (g)</td>
<td>-46.11</td>
</tr>
<tr>
<td>H$_2$O (g)</td>
<td>-241.8</td>
</tr>
<tr>
<td>NH$_4$Cl (s)</td>
<td>-314.4</td>
</tr>
<tr>
<td>HCl (g)</td>
<td>-92.31</td>
</tr>
<tr>
<td>C$_2$H$_4$ (g)</td>
<td>52.26</td>
</tr>
<tr>
<td>C$_2$H$_6$ (g)</td>
<td>-84.68</td>
</tr>
</tbody>
</table>