Chem. 1C Midterm 2
Practice Test 2

Name__________________________________________
Student Number _________________________________

All work must be shown on the exam for partial credit. Points will be taken off for incorrect or no units. Calculators are allowed. Cell phones may not be used for calculators. On fundamental and short answer problems you must show your work in order to receive credit for the problem. If your cell phone goes off during the exam you will have your exam removed from you.

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**Fundamental Questions**

Each of these fundamental chemistry questions is worth 6 points. **You must show work to get credit.** Little to no partial credit will be rewarded. Make sure to include the correct units on your answers.

1)  **6 pts**  What is the name of \([\text{Fe(H}_2\text{O})_5\text{(OH)}]\text{Cl}_2\)?

**Answer:** pentaaquahydroxoiron(III) chloride

What is the formula of Ammonium diaquabis(oxalato)nickelate(II)

\[(\text{NH}_4)_2\text{[Ni(C}_2\text{O}_4)_2\text{(H}_2\text{O})_2]\]

2)  **6 pts**  A student dissolves 6.3 g of methanol (\(\text{CH}_3\text{OH}\)) in 150.0 mL of a solvent with a density of 0.92 \(\frac{\text{g}}{\text{mL}}\). The student notices that the volume of the solvent does not change when the methanol dissolves in it. Calculate the molarity and molality of the student's solution.

\[
M = \frac{n_{\text{solute}}}{V_{\text{solution}}} = \frac{n_{\text{CH}_3\text{OH}}}{V_{\text{solution}}}
\]

\[
n_{\text{CH}_3\text{OH}} = 6.3 \text{g} \left( \frac{1 \text{mol} \text{ CH}_3\text{OH}}{32.05 \text{g} \text{ CH}_3\text{OH}} \right) = 0.197 \text{mol CH}_3\text{OH}
\]

\[
V_{\text{solution}} = V_{\text{solvent}} = 150.0 \text{mL} = 0.1500 \text{L}
\]

Note: problem states that the volume of solution did not change when methanol was added.

\[
M = \frac{0.197 \text{mol}}{0.1500 \text{L}} = 1.31M
\]

\[
m = \frac{n_{\text{solute}}}{m_{\text{solvent}}} = \frac{n_{\text{CH}_3\text{OH}}}{m_{\text{solvent}}}
\]

\[
m_{\text{solvent}} = 150.0 \text{mL} \left( \frac{0.92 \text{g}}{1 \text{mL}} \right) = 140 \text{g} = 0.14 \text{kg}
\]

\[
m = \frac{0.197 \text{mol}}{0.14 \text{kg}} = 1.4 \text{mol/kg}
\]

3)  **6 pts**  The \([\text{CrCl}_6]^{3-}\) ion has a maximum absorbance spectrum at 735 nm. Calculate the crystal field splitting energy in \(\text{kJ/mol}\) for this ion.

\[
\Delta_0 = \frac{hC}{\lambda} = \left( \frac{6.626 \times 10^{-34} \text{ J} \cdot \text{s}}{2.99 \times 10^8 \text{ m/s}} \right) \left( \frac{735 \times 10^{-9} \text{ m}}{735 \times 10^{-9} \text{ m}} \right) = 2.70 \times 10^{-19} \text{ J}
\]

This is the energy per photon change to per mol of photons

\[
\left( 2.70 \times 10^{-19} \frac{\text{J}}{\text{photon}} \right) \left( \frac{6.02214 \times 10^{23} \text{ photon}}{1 \text{mol}} \right) \left( \frac{1 \text{kJ}}{1000 \text{J}} \right) = 162 \text{ kJ/mol}
\]
4) 6 pts  If the partial pressure of oxygen is 0.14 atm at 298 K and Henry’s constant for O₂ in H₂O is 4.34×10⁴ atm. What is the molar solubility (in \( \frac{\text{mol}}{L} \)) of the O₂ in the water?

Hint: It might be helpful to assume you have 1.0 L of H₂O. H₂O has a density of 1.0 \( \frac{\text{g}}{\text{cm}^3} \).

\[
P_{O_2} = K_H \chi_{O_2}
\]

\[
0.14 \text{atm} = (4.34 \times 10^4 \text{atm}) \chi_{O_2}
\]

\[
\chi_{O_2} = 3.2 \times 10^{-6} = \frac{n_{O_2}}{n_{O_2} + n_{H_2O}}
\]

Determine the moles of H₂O

\[
1.0 \text{L H}_2\text{O} \left( \frac{1000\text{mL}}{1\text{L}} \right) \left( \frac{1\text{cm}^3}{1\text{mL}} \right) \left( \frac{1.0\text{g}}{18.02\text{g}} \right) = 55.5 \text{mol}
\]

Determine moles of O₂

\[
3.2 \times 10^{-6} = \frac{n_{O_2}}{n_{O_2} + 55.5 \text{mol}}
\]

\[
n_{O_2} = 1.8 \times 10^{-7} \text{mol}
\]

Determine molarity

\[
M = \frac{n}{V} = \frac{1.8 \times 10^{-7} \text{mol}}{1.0 \text{L}} = 1.8 \times 10^{-4} M
\]

5) 6 pts  What is the 1) oxidation number (on the metal), 2) the electron configuration for Co^{x} (x is the oxidation number found in 1) and 3) coordination number for [Co(ox)₃]^{3-}?

1) Co^{3+}
2) [Co^{3+}] = [Ar]3d^6
3) 6

6) 6 pts  When pure methanol is mixed with water, the solution gets warmer to the touch. Draw a graph showing the vapor pressure as a function of the mole fraction of water, \( \chi_{H_2O} \).
Short Answer Questions

Each of the following short answer questions are worth the noted points. Partial credit will be given. You must show your work to get credit. Make sure include proper units on your answer.

1) 14 pts  A 1.60 g sample of a mixture of naphthalene (C₁₀H₈) and anthracene (C₁₄H₁₀) is dissolved in 20.0 g of benzene (C₆H₆). The freezing point of the solution is 2.81°C. What is the composition of the sample mixture in terms of mass percent? The freezing point of benzene is 5.51°C and Kᵢ is 5.12 kg/mol.

Need to calculate mass% C₁₀H₈ and C₁₄H₁₀

\[
\text{mass } \% \ C_{10}H_8 = \left( \frac{m_{C_{10}H_8}}{m_{\text{total}}} \right) \times 100\% = \left( \frac{m_{C_{10}H_8}}{1.60\text{ g}} \right) \times 100\%
\]

\[
\text{mass } \% \ C_{14}H_{10} = 1 - \text{mass } \% \ C_{10}H_8
\]

Find mass of C₁₀H₈

Know

\[1.60\text{ g} = m_{C_{10}H_8} + m_{C_{14}H_{10}}\]  \[T_f = 2.81^\circ\text{C}\]

Calculate \(\Delta T_f\)

\[T_f = T_f^* - \Delta T_f\]  \[2.81^\circ\text{C} = 5.51^\circ\text{C} - \Delta T_f\]

\[\Delta T_f = 2.70^\circ\text{C}\]

Solve for mass of C₁₀H₈

\[\Delta T_f = \frac{imK_f}{M_{C_{10}H_8}} = i \left( \frac{n_{C_{10}H_8} + n_{C_{14}H_{10}}}{M_{C_{10}H_8}} \right) K_f
\]

\[2.70^\circ\text{C} = \left( 1 \right) \left( \frac{m_{C_{10}H_8} + m_{C_{14}H_{10}}}{0.0200\text{ kg}} \right) \left( 5.12 \frac{^\circ\text{C} \cdot \text{kg}}{\text{mol}} \right)
\]

\[0.0105 \text{ mol} = \frac{m_{C_{10}H_8}}{128.18 \frac{\text{g}}{\text{mol}}} + \frac{m_{C_{14}H_{10}}}{178.24 \frac{\text{g}}{\text{mol}}}
\]

\[m_{C_{14}H_{10}} = 1.60\text{ g} - m_{C_{10}H_8}
\]

\[0.0105 \text{ mol} = \frac{m_{C_{10}H_8}}{128.18 \frac{\text{g}}{\text{mol}}} + \frac{1.60\text{ g} - m_{C_{10}H_8}}{178.24 \frac{\text{g}}{\text{mol}}} = \frac{50.06 \frac{\text{g}}{\text{mol}} m_{C_{10}H_8} + 205.09 \frac{\text{g}^2}{\text{mol}^2}}{22846 \frac{\text{g}^2}{\text{mol}^2}}
\]

\[m_{C_{10}H_8} = 0.695\text{ g}
\]

\[\text{mass } \% \ C_{10}H_8 = \left( \frac{m_{C_{10}H_8}}{m_{\text{total}}} \right) \times 100\% = \left( \frac{0.695}{1.60\text{ g}} \right) \times 100\% = 43.4\% \ C_{10}H_8
\]

\[\text{mass } \% \ C_{14}H_{10} = 100 - 43.4\% = 56.6\%
\]
2a) 8 pts  
Two chemists prepared a complex and determined its formula, which they wrote as \([\text{CrNH}_3\text{Cl}_3] \cdot 2\text{H}_2\text{O}\). However, when they dissolved 2.11 g of the compound in water and added an excess of silver nitrate, 2.87 g of AgCl precipitated and they realized that the formula was incorrect. Write the correct formula of the compound and draw the structure of the complex ion, including all possible isomers. Assume the complex ion has square planar geometry. You must show work for how you arrived at the correct formula to get credit.

Determine the moles of Cl\(^-\) that precipitated:

\[
\frac{2.87 \text{ g AgCl}}{142.323 \text{ g AgCl/mol}} \cdot \frac{1 \text{ mol Cl}^-}{1 \text{ mol AgCl}} = 0.0201 \text{ mol Cl}^-
\]

Therefore, 0.0201 mol of Cl\(^-\) must be present as counter ions. Note: if the Cl\(^-\) was part of the coordination complex then it would not dissociate and react with Ag\(^+\).

Determine the moles of the coordination complex:

\[
\frac{2.11 \text{ g } [\text{CrNH}_3\text{Cl}_3] \cdot 2\text{H}_2\text{O}}{211.4153 \text{ g } [\text{CrNH}_3\text{Cl}_3] \cdot 2\text{H}_2\text{O/mol}} = 0.00998 \text{ mol } [\text{CrNH}_3\text{Cl}_3] \cdot 2\text{H}_2\text{O}
\]

Therefore each time two of the complex ion is dissolved 0.0201 mol of Cl\(^-\) are produced. This mean two of the Cl\(^-\) ions must be counter ions. This results in the formula

\([\text{Cr(H}_2\text{O})_2\text{NH}_3\text{Cl}]\text{Cl}_2\)

Isomers

\[
\begin{array}{c}
\text{H}_3\text{N} \\
\text{H}_2\text{O} \\
\text{Cr} \\
\text{O} \\
2^+ 
\end{array}
\quad
\begin{array}{c}
\text{H}_3\text{N} \\
\text{H}_2\text{O} \\
\text{Cr} \\
\text{O} \\
2^+
\end{array}
\]

2b) 6 pts  
The complexes \([\text{Co(NH}_3)_6]^{2+}\), \([\text{Co(H}_2\text{O})_6]^{2+}\), and \([\text{CoCl}_4]^{2-}\) (tetrahedral) form colored solutions. One is red, one yellow, and the third blue. Use the spectrochemical series and the relative magnitudes of \(\Delta_o\) and \(\Delta_t\) to match each color to a complex. You must explain your reasoning to get full credit.

\(\Delta_o > \Delta_t\) therefore \([\text{CoCl}_4]^{2-}\) will have the smallest splitting because it is the only tetrahedral structure.

\(\text{NH}_3\) is a stronger field ligand than \(\text{H}_2\text{O}\). Therefore the largest crystal field splitting is in the complex \([\text{Co(NH}_3)_6]^{2+}\).

The complexes in order of increasing field splitting:

\([\text{CoCl}_4]^{2-} < [\text{Co(H}_2\text{O})_6]^{2+} < [\text{Co(NH}_3)_6]^{2+}\)

<table>
<thead>
<tr>
<th>Color of Complex</th>
<th>Color absorbed by complex</th>
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<tbody>
<tr>
<td>Red</td>
<td>Green</td>
</tr>
<tr>
<td>Yellow</td>
<td>Violet</td>
</tr>
<tr>
<td>Blue</td>
<td>Orange</td>
</tr>
</tbody>
</table>

The crystal field splitting can be calculated using

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

Therefore, the smaller the wavelength (absorbed) the greater the energy. Causing the blue compound (which absorbs orange) to have the smallest crystal field splitting. The color in order of increasing energy: Blue < Red < Yellow. Therefore: \([\text{CoCl}_4]^{2-}\) is Blue, \([\text{Co(H}_2\text{O})_6]^{2+}\) is Red, and \([\text{Co(NH}_3)_6]^{2+}\) is Yellow.
Multiple Choice Questions

Each of the following multiple choice questions are worth 6 points. Your answers need to be filled in on the Scantron provided. Note: Your Scantrons will not be returned to you, therefore, for your records, you may want to mark your answers on this sheet. On the Scantron you need to fill in your perm number, test version, and name. Failure to do any of these things will result in the loss of 1 point. Your perm number is placed and bubbled in under the “ID number”. Do not skip boxes or put in a hyphen. In addition, leave bubbles blank under any unused boxes. The version number (A) is bubbled in under the “test form.”

1. What color light is needed for photosynthesis?
   A) Green
   B) Red
   C) Violet
   D) Yellow
   E) Blue

2. Which of the following is diamagnetic?
   A) [Co(OH)₆]²⁺
   B) [Cr(NH₃)₆]³⁺
   C) [Fe(CN)₆]³⁻
   D) [Fe(OH)₂]²⁺
   E) [Co(NH₃)₆]³⁺

3. Using the data below, calculate the vapor pressure of chloroform over a chloroform-benzene solution at 25°C, which contains 50.0 g of CHCl₃ and 50.0 g of C₆H₆. Assume that the solution behaves ideally.

<table>
<thead>
<tr>
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<th>Vapor pressure at 25°C</th>
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<tbody>
<tr>
<td>benzene (C₆H₆)</td>
<td>94.4 torr</td>
</tr>
<tr>
<td>chloroform (CHCl₃)</td>
<td>172.0 torr</td>
</tr>
</tbody>
</table>

   A) 125 torr
   B) 172 torr
   C) 68.0 torr
   D) 148 torr
   E) none of these
4. A solute added to a solvent raises the boiling point of the solution because
   A) the solute increases the volume of the solution, and an increase in volume requires an increase in the temperature to reach the boiling point (derived from \( PV = nRT \)).
   B) the temperature to cause boiling must be great enough to boil not only the solvent but also the solute.
   C) Two of the above are correct.
   D) the solute particles raise the solvent's vapor pressure, thus requiring a higher temperature to cause boiling.
   E) the solute particles lower the solvent's vapor pressure, thus requiring a higher temperature to cause boiling.

5. Which of the following complexes is (are) chiral?

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
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</thead>
<tbody>
<tr>
<td>A</td>
<td>D</td>
<td>B</td>
<td>C</td>
</tr>
<tr>
<td>B</td>
<td>D</td>
<td>A</td>
<td>C</td>
</tr>
<tr>
<td>B</td>
<td>A</td>
<td>D</td>
<td>C</td>
</tr>
<tr>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
</tr>
</tbody>
</table>

A) 1 and 3
B) 3
C) 4
D) 2
E) none of these

6. A solution contains 1 mol of liquid A and 3 mol of liquid B. The vapor pressure of this solution is 314 torr at 25°C. At 25°C, the vapor pressure of liquid A is 265 torr and the vapor pressure of liquid B is 355 torr. Which of the following is true?
   A) This solution exhibits a negative deviation from Raoult's law.
   B) This solution is ideal.
   C) This solution exhibits a positive deviation from Raoult's law.